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"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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## ERRATUM

Vondracek, Bruce, Larry R. Brown, and Joseph J. Cech. 1982. Comparison of age, growth, and feeding of the Tahoe sucker from Sierra Nevada streams and a reservoir. Calif. Fish Game, 68(1): 36-46.

Page 41, Figure 3. The equations shown on Figure 3 should be changed to read as follows: Stampede Reservoir, LOG W = −3.576 + 2.487 LOG L; Sagehen Creek, LOG W = −4.314 + 2.787 LOG L; Little Truckee River, LOG W = −4.083 + 2.677 LOG L.

*Calif. Fish and Game* 70(3): 132—139 1984

# DISTRIBUTIONS OF SOME COMMON DECAPOD CRUSTACEANS AND A PYCNOGONID FROM THE CONTINENTAL SHELF OF NORTHERN CALIFORNIA [1]

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**Ten decapods and the pycnogonid *Nymphon pixellae* were taken at more than three stations by the R. V. SEARCHER by otter trawling. Collections were made from off Trinidad Head to off Bodega Bay. *Pandalus danae* and *Oregonia gracilis* occurred at 92 m or less on mixed bottoms. Crabs of the genus *Cancer* usually lived at similar depths on sand. At 37–92 m on sand, *Pagurus armatus, Crangon spinosissima,* and *Spirontocaris lamellicornis* were collected. *Pandalus jordani* usually was taken on mud deeper than 92 m. *Spirontocaris holmesi* was found primarily deeper than 130 m. *Crangon alaskensis* and *N. pixellae* were taken throughout the depth range sampled, 15–185 m. These records agree with other published records of decapods taken in the area. *Sicyonia ingentis* and *Cancer anthonyi,* common on the continental shelf of southern California, have not been trawled off northern California.**

## INTRODUCTION

The soft bottoms of the continental shelf off northern California have long been known for yielding rich harvests of decapod crustaceans. The major commeaaaal species of the area are the Dungeness crab, *Cancer magister,* and the ocean shrimp, *Pandalus jordani.*

The most extensive study of benthic decapods in the area between San Francisco and Oregon was that of the steamer *Albatross* in January 1912–April 1913. Dredging operations included some areas just outside the Golden Gate, but were concentrated in San Francisco Bay (Schmitt 1921). Goodwin (1952) reported on collections made by the N. B. SCOFIELD using a beam trawl off Humboldt County, Fort Bragg, and Drakes Bay. A few specimens of decapods taken by commercial fishermen in the area have been donated to the collections of the California Academy of Sciences (CAS) and the Allan Hancock Foundation (AHF), University of Southern California. In 1971, the R. V. SEARCHER, under the auspices of the Los Angeles County Museum of Natural History, collected specimens by otter trawling at 35 stations from 12.5 miles north of Trinidad Head, Humboldt County to off Tomales Point, Marin County.

It can be very difficult to collect marine specimens off northern California. Strong winds, rough seas, and harsh weather prevent regular sampling. Except for the two commercial species, decapod crustaceans are not sufficiently common to obtain in quantities suitable for statistical analysis. Finer definitions of the distributions of the species discussed here await more detailed sampling programs.

[1] Accepted for publication July 1983.

## METHODS

At the Allan Hancock Foundation, I sorted and identified to species the crustaceans and pycnogonid taken by the R. V. SEARCHER. These specimens were collected with an otter trawl towed for 20 minutes at various stations (Figure 1 and Table 1). Further information on the stations of the SEARCHER is available through the Allan Hancock Foundation (Crustacea Section) and the Los Angeles County Museum of Natural History (Division of Ichthyology). I also examined at the California Academy of Sciences other specimens taken by the SEARCHER off Marin County.

**TABLE 1. List of R. V. SEARCHER Stations**

HUMBOLDT COUNTY:

August 5, 1971:
173: 12.5 mi. N. of Trinidad Harbor, 55 m
176: 12 mi. NNW of Trinidad Harbor, 110 m
177: 12 mi. NW of Trinidad Harbor, 129 m
178: 10.5 mi. NW of Trinidad Harbor, 148 m
179: 10 mi. NW and W of Trinidad Harbor, 166 m
180: 9.5 mi. W of Trinidad Harbor, 185 m

August 6, 1971:
184: 8 mi. NNW of Cape Mendocino, 65 m
185: 8 mi. NW of Cape Mendocino, 83 m
186: 5.5 mi. SW of Pt. Delgada, 138 m
187: 5 mi. SW of Pt. Delgada, 92 m
188: 2 mi. SW of Pt. Delgada, 46 m

July 29, 1971:
159: 1 mi. W of Pt. Delgada, 24 m

August 7, 1971:
189: 1 mi. S of Shelter Cove, 24 m
190: 2 mi. S of Shelter Cove, 28 m
191: 3 mi. S of Shelter Cove, 31 m
192: 5 mi. S of Shelter Cove, 37 m

MENDOCINO COUNTY:

August 7, 1971:
193: 9 mi. NW of Fort Bragg, 138 m
194: 5 mi. N of Fort Bragg, 92 m
195: 4.5 mi. N of Fort Bragg, 74 m
196: 6 mi. N of Fort Bragg, 55 m
197: 7 mi. N of Fort Bragg, 37 m

August 8, 1971:
199: 6 mi. S of Fort Bragg, 102 m
200: 8.5 mi. SW of Fort Bragg, 138 m
201: 12 mi. SW of Fort Bragg, 185 m

August 9, 1971:
205: 1 mi. S of Arena Cove Buoy, 55 m
207: Gualala Point, depth not recorded
208: 12 mi. S of Pt. Arena, 92 m or less

**TABLE 1. Continued**

July 27, 1971:

152: 1.5 mi. from Arena Cove Pt., 55 m
153: 1.25 mi. abeam of Arena Cove Buoy, depth not recorded

SONOMA–MARIN COUNTIES:

August 10, 1971:

209: 0.5 mi. SSW of Mile Rocks, 19 m
210: 1 mi. SW of Gull Rock, 28 m
211: 1.5 mi. W of Duncan's Landing, 37 m
213: 1 mi. W of Bodega Head, 55 m

August 20, 1971:

A: 1.45 mi. NNW of Tomales Pt., 31–43 m
B: 0.25 mi. N of Tomales Pt., 15–18 m
C: 1 mi. S of Bodega Head, 55 m
D: 3 mi. N X W of Tomales Pt., 74 m

Note: the stations of August 20 were not assigned numbers.
I have given them letter designations.

Records of the ten decapods and one pycnogonid taken at three or more stations of the SEARCHER are published here for the first time. Range extensions of other, less common species taken in the area are published elsewhere (Haig and Wicksten 1975; Wicksten 1976, 1984). The records of the species taken by the SEARCHER were compared with records given by Schmitt (1921) and Goodwin (1952) for the coast of northern California, Butler (1980) for British Columbia, Word and Charwat (1976) and Wicksten (1980) for the continental shelf of southern California.

## RESULTS

The SEARCHER collected 21 species of decapods off northern California by trawling. Of these, only six shrimp, one hermit crab, and three brachyuran crabs occurred at three or more stations (Table 2). These species also varied by depth (Table 3).

*Crangon alaskensis* was by far the most common decapod taken by the *SEARCHER*. Up to 175 (at station 159) were collected in a single tow (Table 2). A total of 29 *C. alaskensis* from 14 stations were infected with bopyroid isopods.

*Pagurus armatus* was the only anomuran common in trawls. The shells it inhabited were covered by a hydroid, *Hydractinia* sp.

## DISCUSSION

From the records of the specimens taken by the *SEARCHER*, nine out of eleven common species tend to be more common at certain ranges of depth. *Pandalus danae, Oregonia gracilis,* and the two species of *Cancer (jordani* and *magister)* were only collected at depths of 92 m or less. *Spirontocaris lamellicornis, Crangon spinosissima,* and *Pagurus armatus* were most abundant at 46–92 m, although *P. armatus* also was taken at shallower and greater depths. *P. jordani* and *S. holmesi* were taken mostly at more than 92 m. These depth ranges are consistent with previous records of the species, although all have been reported

at greater and lesser depths (Schmitt 1921, Goodwin 1952, Garth 1958, McLaughlin 1974, Butler 1980, Garth and Abbott 1980). *Crangon alaskensis* was taken at depths from less than 19 m to 185 m. *Nymphon pixellae* also occurred at a wide range of depths.

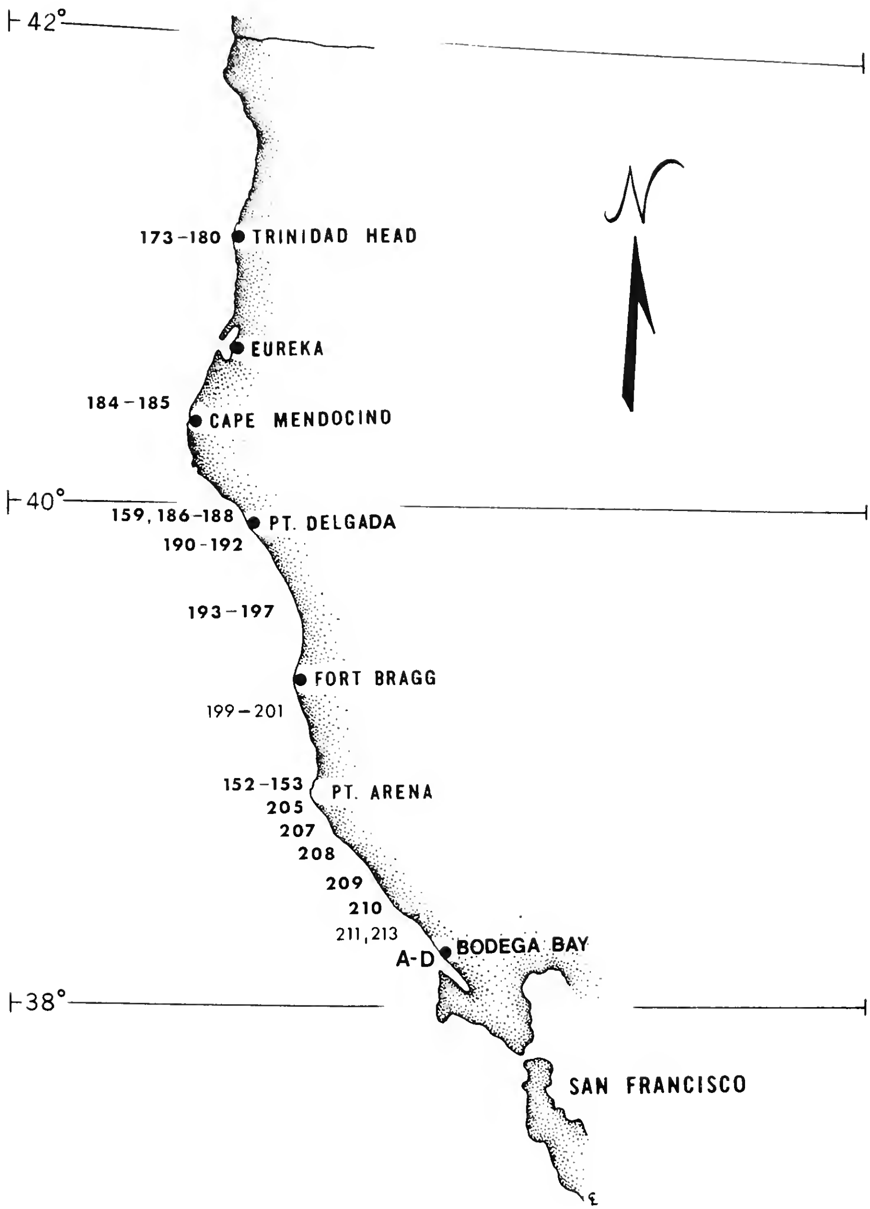


FIGURE 1. Station locations.

**TABLE 2. Species by Station**

CLASS CRUSTACEA, ORDER DECAPODA:

Section Caridea:

*Crangon alaskensis* Lockington
Stations and number of specimens per station: 152 (28), 159 (175), 173 (85), 176 (13), 177 (25), 178 (39), 179 (6), 180 (20), 184 (20), 185 (30), 186 (20), 187 (11), 188 (25), 189 (37), 190 (109), 191 (95), 192 (82), 193 (5), 194 (70), 195 (47), 196 (94), 197 (16), 199 (47), 201 (19), 205 (44), 207 (20), 208 (32), 209 (44), 210 (166), 211 (35).

*Crangon spinosissima* Rathbun
187 (1), 194 (8), 195 (1), 199 (7), 205 (1), 213 (9).

*Pandalus danae* Stimpson
189 (28), 192 (2), 213 (23), A (3), D (2).

*Pandalus jordani* Rathbun
176 (24), 177 (15), 178 (37), 179 (28), 180 (33), 186 (28), 187 (1), 193 (1), 201 (4), 207 (1).

*Spirontocaris holmesi* Holthuis
178 (2), 179 (5), 201 (8).

*Spirontocaris lamellicornis* (Dana)
152 (1), 173 (4), 184 (4), 185 (1), 186 (1), 195 (1).

Section Anomura:

*Pagurus armatus* (Dana)
152 (1), 173 (23), 179 (1), 184 (6), 185 (1), 192 (2), 195 (8), 196 (3), 197 (1), 201 (5), 205 (24), 207 (7), 208 (1), 209 (1).

Section Brachyura:

*Cancer jordani* Rathbun
196 (1), 209 (2), 211 (1).

*Cancer magister* Dana
208 (3), 209 (2), 210 (2).

*Oregonia gracilis* Dana
153 (1), 159 (1), 196 (3), 197 (1), 210 (2), 211 (4), A (1), D (1).

CLASS PYCNOGONIDA:

*Nymphon pixellae* Scott
186 (8), 187 (49), 190 (1), 195 (5), 197 (2).

Substrate is important in the distribution of benthic decapods. *P. danae* lives on bottoms of sand and gravel or shell (Schmitt 1921, Butler 1980). *O. gracilis* occurs on various substrates, including rocks (Garth 1958). *Cancer magister* lives buried in sand (Garth and Abbott 1980). *Crangon alaskensis, C. spinosissima,* and *Pagurus armatus* have been reported from sandy bottoms (Schmitt 1921, Butler 1980). *S. lamellicornis* has been found on bottoms of mud or sand (Butler 1980). *P. jordani* lives on bottoms of green mud (Goodwin 1952, Pruter and Harry 1952, Butler 1980). There are no previous reports of the substrate preferences of *S. holmesi, C. jordani,* and *N. pixellae.* Judging from their occurrences by depth, however, one might guess that they inhabit mud, sand, and sand or mud, respectively.

**TABLE 3. Distribution of Species by Depth**

| | Total at Depth Interval in Fathoms | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Species* | *0–10* | *11–20* | *21–30* | *31–40* | *41–50* | *51–60* | *61–70* | *71–80* | *81–90* | *91–100* |
| *Cancer jordani* | 2 | 1 | 1 | | | | | | | |
| *Cancer magister* | 2 | 2 | | | 3 | | | | | |
| *Crangon alaskensis* | 44 | 715 | 276 | 67 | 143 | 60 | 25 | 64 | 6 | 39 |
| *Crangon spinosissima* | | | 10 | 1 | 9 | 7 | | | | |
| *Nymphon pixellae* | | 3 | | 5 | 49 | | | 8 | | |
| *Oregonia gracilis* | | 8 | 4 | 1 | | | | | | |
| *Pagurus armatus* | 1 | 3 | 51 | 14 | 2 | | | | 1 | 5 |
| *Pandalus danae* | | 2 | 26 | 2 | | | | | | |
| *Pandalus jordani* | | | | | 1 | 24 | 15 | 66 | 28 | 37 |
| *Spirontocaris holmesi* | | | | | | | | 2 | 5 | 8 |
| *Spirontocaris lamellicornis* | | | 5 | 5 | 1 | | | 1 | | |
| depth in m | 0–19 | 21–37 | 39–55 | 57–74 | 76–92 | 94–111 | 113–129 | 131–148 | 159–166 | 168–185 |

Note: depth not recorded for 20 *Crangon alaskensis*, 1 *Oregonia gracilis*, 7 *Pagurus armatus*, 28 *Pandalus danae* and 1 *Pandalus jordani*.

The eleven common species taken by the SEARCHER seem to form three groups. The first, the shallowest group, contains species of mixed bottoms (*P. danae* and *O. gracilis*) and sandy bottoms (the two species of *Cancer*). At intermediate depths a second group lives on sand, containing *S. lamellicornis, P. armatus,* and *C. spinosissima, P. jordani* and *S. holmesi* form a deep group, living on mud. *Crangon alaskensis* and *N. pixellae* occur throughout the entire range of depths.

All of the eleven common species mentioned here occur north of California, ranging as far as Alaska or British Columbia (Scott 1912, Schmitt 1921, McLaughlin 1974, Butler 1980). To the south, however, three species reach their southern limits. *O. gracilis* has not been reported south of Monterey Bay, California (Garth 1958). *Cancer magister* has been reported once from Santa Barbara, but the southernmost sizable population is in the area of Avila to Morro Bay, San Luis Obispo County (Garth and Abbott 1980). *S. lamellicornis* has been reported once from Point Conception and once from Santa Monica Bay (Standing 1981, Word 1983). *Crangon alaskensis* is common on the shelf of both northern and southern California. The other seven species range into southern California, but have not been reported as common in trawls (Word and Charwat 1976, Wicksten 1980).

Two decapods common off southern California in trawls were not collected on the continental shelf of northern California. The peneid prawn, *Sicyonia ingentis,* has not been collected north of Santa Barbara County (AHF unpubl. data). The yellow crab, *Cancer anthonyi,* ranges north to Humboldt Bay, California, but has been said to be "uncommon north of San Pedro" (Garth and Abbott 1980). From records I have seen, this crab seems to inhabit sheltered waters north of San Pedro. The crab has been collected at King Harbor, Redondo Beach (Straughan 1978); Princeton Harbor, San Mateo County (MKW, unpubl. field notes), Fort Baker, San Francisco Bay and Bodega Bay (AHF unpubl. data) and Humboldt Bay (Willis 1968). Both the crab and the prawn probably prefer warmer, more protected waters than the common species of the northern coast.

## ACKNOWLEDGMENTS

I thank J. Garth, J. Haig, and R. Brusca for their help while I worked at the Allan Hancock Foundation and D. Chivers and W. Lee for assistance at the California Academy of Sciences. D. Gotshall of the California Department of Fish and Game gave helpful suggestions on the original manuscript. C. Swift, Los Angeles County Museum of Natural History, donated specimens and provided data from the collections of the *SEARCHER* to the Allan Hancock Foundation. The operations of the *SEARCHER* were supported by the Janss Foundation, Thousand Oaks, California.

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# DIURNAL ACTIVITY AND HABITAT USE BY FERAL PIGS ON SANTA CRUZ ISLAND, CALIFORNIA [1]

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**Feral pigs, *Sus scrofa,* on Santa Cruz Island were active mornings and evenings during fall and spring and were active at midday during winter. Canyon bottoms were frequented in fall and early winter, with a shift to ridgetops during late winter and spring. Pigs occurred most often in chaparral and oak woodland in fall, then moved to chaparral-grassland and grassland from midwinter through spring. Activity and distribution of pigs were related to seasonal changes in temperature and food availability, and to availability of escape cover.**

## INTRODUCTION

Feral pigs were introduced to California in 1769 and have become the second most abundant big game species in the state (Barrett 1978). Although popular as a game animal, pigs can cause severe damage to natural ecosystems and agricultural lands (Wood and Barrett 1979). Despite their importance, feral pigs in California have received relatively little study. Published descriptions of diurnal activity and habitat use are largely qualitative (Pine and Gerdes 1973, Barrett 1978, Mansfield 1978, Barrett and Pine 1981); only Barrett (1982) has reported quantitative data on habitat use by pigs. My objective was to evaluate seasonal patterns of diurnal activity, distribution on slopes, and use of plant communities by feral pigs on Santa Cruz Island, California. This information will help identify those areas where damage by feral pigs is most likely to occur.

## STUDY AREA

Santa Cruz Island is about 25,000 ha in size, 40 km offshore of Santa Barbara, Santa Barbara County. The climate is the Mediterranean type characteristic of much of California, with hot, dry summers and cool, wet winters. Most of the 52 cm average annual precipitation falls as rain between November and April. Free water was available in most canyons on the island throughout the study. Topography of most of the island is rugged, with a maximum elevation of 750 m. Plant communities were described by Philbrick and Haller (1977) and mapped by Minnich (1980), who reported that 84% of the island supported grassland, chaparral, and oak woodland communities. Feral pigs have inhabited Santa Cruz Island since at least the 1920's (Rogers 1929), and possibly since the mid-1800's (Brumbaugh 1980). In 1964, McKnight (1964:44) reported "several thousand" on Santa Cruz, Santa Rosa, and Santa Catalina islands. Population size on Santa Cruz Island at the time of my study was unknown.

## METHODS

I obtained data on feral pigs through visual surveys, by foot or from a vehicle, conducted almost daily from 24 October 1979 through 19 May 1980. Because of limited road access and other constraints, survey effort was not distributed uniformly over the island; however, about two-thirds of the island was surveyed

[1] Accepted for publication October 1983.

at least once. For each pig observed, I recorded time of day (PST), location on canyon slope, and plant community. Approximate slope location was determined by visually dividing into thirds (upper, middle, lower) the slope on which each pig stood, and assigning the pig to the appropriate division. Plant community was designated according to dominant vegetation within 30 m of each pig. Community classifications were similar to those of Philbrick and Haller (1977) and Minnich (1980), with one addition; areas dominated by a mixture of chaparral shrubs and open grassy areas were classified as chaparral-grassland. Preference by pigs for each plant community was evaluated with a preference index (Van Dyne and Heady 1965), which was calculated by dividing percent cover on the island (Minnich 1980) into percentage of pigs observed in the community. Minnich (1980) included chaparral-grassland areas in the grassland community, and consequently a single preference index was calculated for both communities. Preference was indicated by an index greater than 1.0.

## RESULTS AND DISCUSSION

### Diurnal Activity

A total of 701 pig observations was recorded during 699 hours of field work. The number of pigs recorded per hour of observation exhibited a bimodal pattern during most of the study, with peaks during morning and evening hours (Figure 1). An exception to this pattern occurred during December and January, when a unimodal pattern was evident. Average number of pigs observed per hour was greatest during February and March, and least during April and May.

Pig activity probably was influenced by seasonal changes in temperature and food availability (Barrett 1978). Mild temperatures in fall (October–November) were associated with a morning and evening activity pattern. Pigs became more active at midday during the short, cool, often rainy days of early winter (December–January). The return of drier, milder weather in late winter (February–March), particularly March, coincided with a return to morning and evening activity. Pigs were observed more often during this period, probably because they had moved into more open habitats to forage and hence were more visible. Frequency of pig observations declined 70% between late winter and spring (April-May), probably because pigs shifted to nocturnal activity as conditions became warm and dry.

### Habitat Use

In October, most pigs were at midslope or in canyon bottoms (Figure 2). By December and January most observations were in canyon bottoms. During February, March, and April, pig activity shifted toward ridgetops, and in May midslopes were used most frequently. Changes in pig distribution on canyon slopes probably were related to a combination of weather conditions and food availability. Santa Cruz Island was very dry from October through mid-December, when pigs generally avoided ridgetops; canyon bottoms were much cooler and water was available in most. Winter storms in January and February brought moisture and growth of herbaceous vegetation, and coincided with movement of pigs to ridgetops. Very little rain fell after March, and most grasses and forbs had dried by May, with a concurrent downslope movement by pigs. Pine and

Gerdes (1973) observed that pigs in Monterey County remained near damp creek bottoms during the dry season and frequented ridgetops in winter and spring.

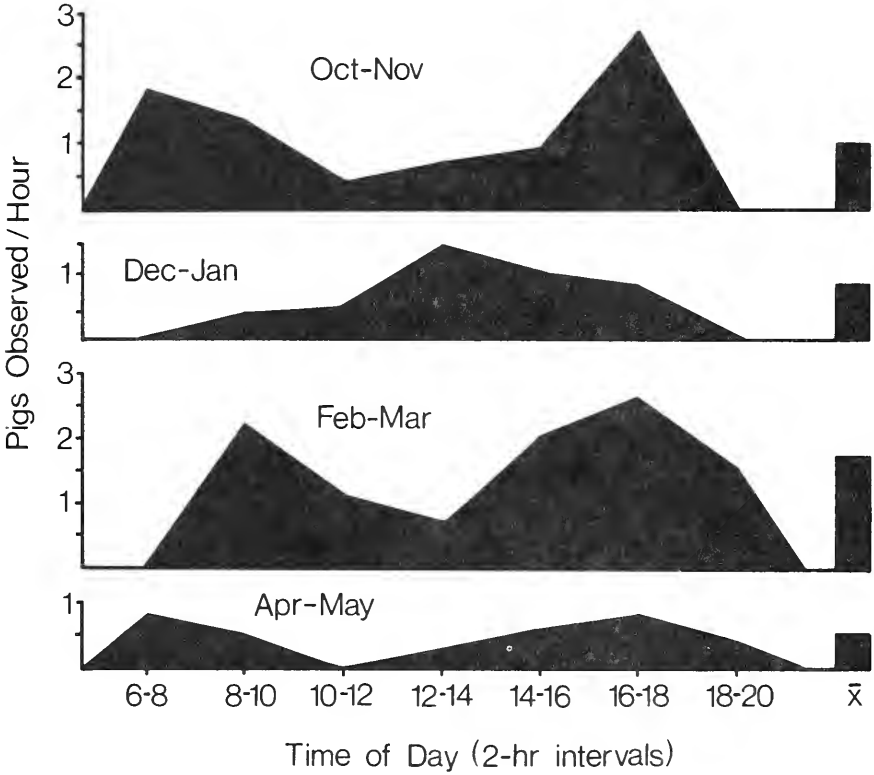


FIGURE 1. Seasonal variation in diurnal activity of feral pigs on Santa Cruz Island.

Evaluation of plant community use and preference by pigs must be considered in light of bias in observations of pigs; survey effort was not distributed equally among plant communities, and pigs were not equally visible in different communities. Chaparral was the community sampled most intensively in proportion to its availability, but it was also the community in which pigs were least visible, tending to cancel some of the bias. Moreover, bias in survey effort was relatively consistent from month to month, and hence comparisons among months probably reflected trends in actual pig distribution.

Most pigs observed in October and November were in chaparral, grassland, or oak woodland (Table 1). In December and January, occurrence in chaparral and oak woodland declined, while occurrence in grassland increased. Beginning in February and March, and continuing through April and May, few pigs were observed in chaparral as they apparently shifted to more open habitats, appearing most often in chaparral-grassland and grassland.

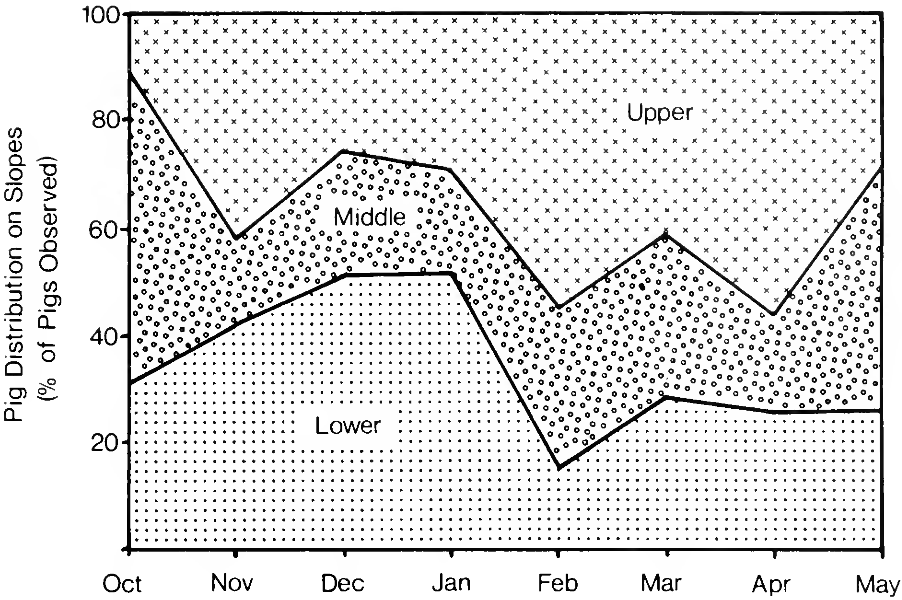


FIGURE 2. Distribution of feral pigs on canyon slopes on Santa Cruz Island.

**TABLE 1. Bimonthly Percentages of Feral Pigs Recorded in Plant Communities on Santa Cruz Island. Preference Indices are in Parentheses.**

| | *Oct–Nov* | *Dec–Jan* | *Feb–Mar* | *Apr–May* | *All months* |
|---|---|---|---|---|---|
| Pig observations | 151 | 147 | 289 | 114 | 701 |
| Chaparral | 45 (1.5) | 36 (1.2) | 2 (0.1) | 5 (0.2) | 19 (0.6) |
| Grassland [1] | 21 (0.7) | 34 (1.0) | 18 (1.7) | 27 (1.8) | 23 (1.3) |
| Chaparral-grassland | 11 | 14 | 61 | 54 | 39 |
| Oak woodland | 23 (3.3) | 11 (1.6) | 9 (1.3) | 10 (1.4) | 12 (1.7) |
| Other | 0 | 5 | 10 | 4 | 7 |

[1] Preference indices calculated from combined grassland and chaparral-grassland data.

Pigs preferred chaparral and oak woodland in October and November (Table 1). Preference for grassland (includes both grassland and chaparral-grassland communities) increased in subsequent months, and by April and May grassland was the most preferred community, while chaparral was least preferred. Oak woodland remained a preferred community throughout the study. Barrett and Pine (1981) reported that habitats which included oak woodland were most preferred by feral pigs in San Benito County, Mansfield (1978) noted that wild pigs in Monterey County depended on oak grassland sites for foraging, and Barrett (1982) found that feral pigs preferred oak thicket vegetation in Tehama County.

Distribution of pigs among plant communities probably was related to changes in food availability. Preferences for chaparral and oak woodland in October and November coincided with acorn production; oaks were an important component of both communities, and acorns were a major food of feral pigs

in California (Pine and Gerdes 1973, Barrett 1978). The shift in activity to chaparral-grassland during February occurred shortly after the first major storm of the season in early January brought new growth of grasses and forbs. Green herbaceous vegetation dominated spring diets of pigs elsewhere in California (Pine and Gerdes 1973, Barrett 1978). Absence of a concurrent shift by pigs into grasslands, where herbaceous vegetation also was available, probably was inhibited by lack of cover in open grasslands. Pig hunters were present on the island throughout the study, and Pine and Gerdes (1973) reported that hunted pigs sought brush for escape cover. Barrett (1978) observed that pigs in Tehama County moved into more open habitats in winter and spring to graze.

Results of this study illustrate and emphasize the importance of weather and food in the activity and distribution of feral pigs. Pigs are highly adaptable, adjusting quickly to seasonal changes in temperature and the availability of two of their most important foods, acorns and green herbaceous vegetation.

Rooting by wild pigs can cause severe damage to vegetation (Wood and Barrett 1979). On Santa Cruz Island, concentration of pigs in canyon bottoms during late fall and early winter indicates a high potential for damage to streamside vegetation and water sources. Chaparral and oak woodland communities were highly preferred during fall. These communities are particularly rich in plant species endemic to the Channel Islands (Philbrick and Haller 1977), and hence the presence of concentrated pig activity constitutes a serious threat to vegetation of the island.

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# ENVIRONMENTAL CONDITIONS AND FISH FAUNAS IN LOW ELEVATION RIVERS ON THE IRRIGATED SAN JOAQUIN VALLEY FLOOR, CALIFORNIA[1]

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**Physical and chemical characteristics of the lower San Joaquin and Merced rivers showed longitudinal (upstream to downstream) patterns related primarily to irrigation activities. Turbidity, total alkalinity, conductivity, and concentrations of macronutrients ($NH_3$-N, $NO_3+NO_2$-N, total N, ortho-$PO_4$, and total P) increased conspicuously at downstream sampling sites. The fish faunas also differed at upstream and downstream sites. Species captured primarily at upstream sites were sculpins, *Cottus* spp.; green sunfish, *Lepomis cyanellus;* redear sunfish, *L. microlophus;* Sacramento squawfish, *Ptychocheilus grandis;* hardhead, *Mylopharodon conocephalus;* and threespine stickleback, *Gasterosteus aculeatus;* species that seemed to be restricted to downstream sites were inland silverside, *Menidia beryllina;* white crappie, *Pomoxis annularis;* threadfin shad, *Dorosoma petenense;* fathead minnow, *Pimephales promelas;* splittail, *Pogonichthys macrolepidotus;* Sacramento blackfish, *Orthodon microlepidotus;* tule perch, *Hysterocarpus traski;* and striped bass, *Morone saxatilis.* Published information on the general habitat requirements of fishes indicates that environmental changes are probably influencing the composition and abundance of fish faunas. Further research is needed to isolate the direct and indirect effects of environmental contaminants on fish, with particular emphasis on identifying the toxic components of irrigation return flows.**

## INTRODUCTION

Dam construction, water withdrawals, contamination by municipal and agricultural wastes, and other man-related activities have contributed toward changes in the fish communities of the San Joaquin Valley (Moyle 1976, Moyle and Nichols 1973, U.S. Bureau of Reclamation 1978), but the full extent of these changes is unknown. Recent studies of fish communities in the Valley have focused either on Sierra Nevada foothill streams and reservoirs above 90 m elevation (e.g., Moyle and Nichols 1973, 1974) or on the Sacramento-San Joaquin Delta (e.g., Turner and Kelley 1966). The fishes of low-elevation rivers on the San Joaquin Valley floor that connect these two major habitat types have not been investigated.

Irrigated agriculture is the dominant land use on the San Joaquin Valley floor (California Department of Water Resources 1960, 1969). During the irrigation season (usually March to October), return flows from irrigated fields can compose most of the discharge in low elevation rivers (California Department of Water Resources 1960, U.S. Bureau of Reclamation 1978). Knowledge of changes in the river environment associated with irrigated agriculture and attendant changes in the fish faunas may contribute toward a better understanding of potential ecological impacts from existing and future irrigation drainage projects.

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This paper reports the results of a survey of general environmental conditions and fishes in low elevation rivers on the San Joaquin Valley floor. Specific objectives of the survey were to: (i) compare the physicochemical environment of rivers from locations at the head of the Valley floor (i.e., above most irrigated croplands) with those within the irrigated areas; (ii) determine the occurrence and relative abundance of fishes at each of the locations; and (iii) relate the measured environmental conditions to the broad habitat requirements of fishes.

## STUDY AREA

The study area included the San Joaquin River and two of its tributaries, the Merced River and Salt Slough (Figure 1). Six sampling sites were established on the San Joaquin River, two on the Merced River, and one on Salt Slough, at elevations ranging from 3 to 79 m above mean sea level. Both the San Joaquin and Merced rivers originate in the Sierra Nevada at elevations exceeding 3,500 m. Their initial water supplies are derived from snowmelt and rainfall; at lower elevations, natural seepage and irrigation return flows make up progressively greater proportions of their flows. Salt Slough originates on the Valley floor, and derives most of its discharge from natural seepage and irrigation return flows.

## MATERIALS AND METHODS

Field sampling extended from July 1980 to November 1981. At each sampling site, I monitored physicochemical variables likely to change from irrigation-related activities (e.g., water diversions, return flows, etc.) and/or to affect fish distribution. The following measurements were made monthly: water temperature, turbidity, discharge (data obtained from the U.S. Geological Survey, the U.S. Bureau of Reclamation, and the California Department of Water Resources), dissolved oxygen, pH, total alkalinity, and conductivity. At 3-month intervals, I also measured macronutrients and the particle size distribution of bottom sediments.

Fish were collected monthly from July 1980 to October 1981 at two sites (SJR-1 and SJR-4; see Figure 1 for explanation of abbreviations). At all other sites, collections were made once every 3 months during the same period, except that collections were terminated in October 1980 at SJR-3 and started in January 1981 at SJR-6. Samples were obtained with two seines, one 5.5 m long by 2.4 m deep with 9.5-mm square mesh, and one 30.5 m long by 1.8 m deep with 12.7-mm square mesh. Fish were also collected by backpack electrofishing at SJR-1, MR-1, and MR-2; other sites were too turbid and salty for effective electrofishing.

Captured fish were identified and counted, and the fish were returned to the water. Species similarity indices for pairs of sampling sites were calculated by using Jaccard's formula, $S_j = T_{ij}/(T_i + T_j - T_{ij})$, where $T_i$ and $T_j$ are the numbers of species at sites i and j, respectively, and $T_{ij}$ is the number of species at both sites (Horwitz 1978). Fish counts for each gear type were also assigned relative abundance ratings according to the following criteria: rare, 0.1 to 1.0% of the mean catch at the sample site; common, 1.1 to 7.0%; and abundant, $>$ 7.0%. Failure to collect a species in an area did not necessarily mean it was absent but strongly suggested that it was very rare. Certain species (e.g., lampreys, *Lampetra* spp.; and sculpins) may have been inadequately sampled by the various gears because these fishes can burrow into the substrate. Also, fast swimmers (e.g., adult striped bass and chinook salmon, *Oncorhynchus tshawytscha*) and

fish that inhabited deep, swift-flowing channels were probably underrepresented in the catches.

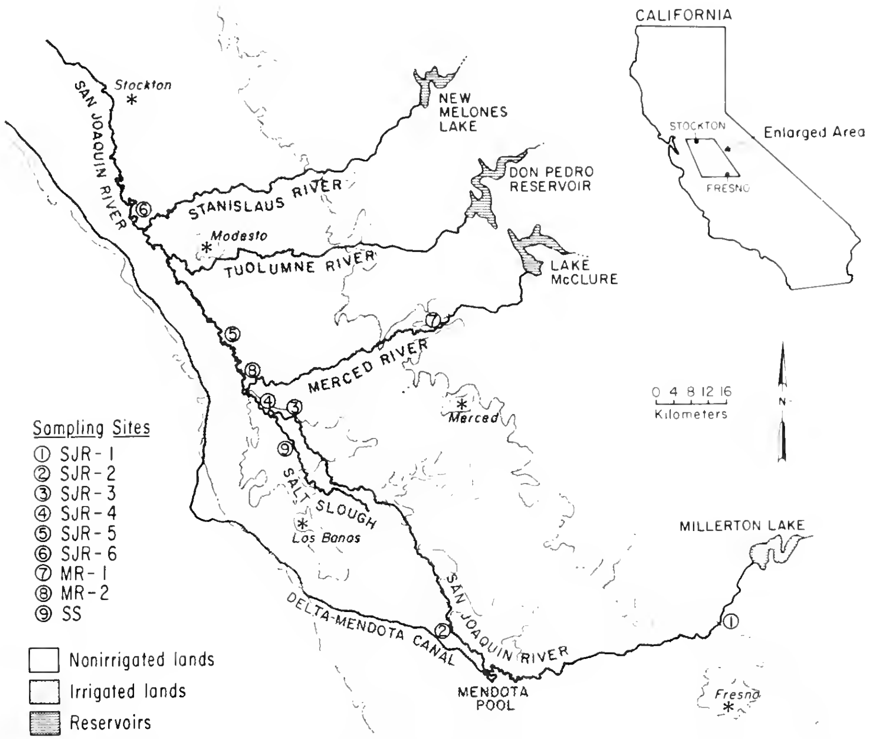


FIGURE 1. Locations of sampling sites and irrigated croplands in the study area. Names of sampling sites are as follows: SJR-1, San Joaquin River near Fort Washington; SJR-2, San Joaquin River at Firebaugh; SJR-3, San Joaquin River at Lander Avenue; SJR-4, San Joaquin River at Fremont Ford State Recreational Area; SJR-5, San Joaquin River near Crows Landing; SJR-6, San Joaquin River at South County Park; MR-1, Merced River below Highway 59; MR-2, Merced River at George J. Hatfield State Recreational Area; and SS, Salt Slough below Lander Avenue.

# RESULTS

## Physicochemical Environment

With the exception of temperature, physicochemical characteristics showed no consistent temporal patterns either within or between sampling sites during this study. Water temperatures were lowest during December–January and highest during July–September. Nearly all variables showed longitudinal (i.e., upstream to downstream) patterns.

Water temperatures in the San Joaquin and Merced rivers were lowest at upstream sites (Table 1). In the San Joaquin River, mean temperatures reached a maximum at SJR-3, then steadily declined from SJR-4 to SJR-6. The declining temperatures coincided longitudinally with inflows of lower temperature water from Salt Slough and the Merced River.

Turbidities were lowest at upstream sites (Table 1), and increased rapidly downstream (less than threefold in the Merced River at MR-2, but over sevenfold in the San Joaquin River at SJR-4). The progressively higher turbidities

measured between SJR-1 and SJR-4 were associated with turbid discharges from the Delta-Mendota Canal (see Figure 1 for location) and several agricultural drains, including Salt Slough. Turbidity in the San Joaquin River decreased below SJR-4, coinciding with inflows of clearer waters from tributary streams such as the Merced River.

**TABLE 1. Water Temperature, Turbidity, and Discharge in the San Joaquin and Merced Rivers, and Salt Slough (mean ± SD; ranges in parentheses).**

| *Site* * | *Temperature (°C)*† | *Turbidity (NTU'S)*† | *Discharge (m³/s)*‡ |
|---|---|---|---|
| SJR-1 | 15.6 ± 4.6 | 3.2 ± 2.1 | 4.5 ± 7.3 |
| | (6.8 – 24.4) | (0.6 – 8.6) | (1.0 – 49.3) |
| SJR-2 | 18.2 ± 5.4 | 18.6 ± 14.9 | 7.1 ± 5.1 |
| | (9.7 – 27.4) | (5.8 – 74.7) | (0.2 – 14.2) |
| SJR-3 | 19.0 ± 6.3 | 21.3 ± 8.9 | 2.5 ± 2.3 |
| | (7.5 – 30.4) | (6.0 – 39.8) | (0.6 – 8.9) |
| SJR-4 | 18.0 ± 6.4 | 25.0 ± 10.1 | 8.3 ± 3.4 |
| | (7.1 – 30.0) | (9.4 – 60.3) | (3.5 – 16.7) |
| SJR-5 | 17.6 ± 5.6 | 20.1 ± 9.4 | 26.0 ± 10.7 |
| | (7.9 – 27.0) | (5.2 – 39.0) | (11.0 – 83.0) |
| SJR-6 | 16.8 ± 5.1 | 17.5 ± 8.9 | 57.4 ± 22.1 |
| | (8.3 – 25.5) | (6.9 – 39.5) | (31.4 – 92.8) |
| MR-1 | 14.3 ± 3.5 | 1.7 ± 0.6 | 6.5 ± 4.2 |
| | (8.5 – 21.0) | (0.5 – 3.2) | (1.4 – 19.1) |
| MR-2 | 18.0 ± 5.8 | 5.7 ± 6.6 | 9.8 ± 4.1 |
| | (8.5 – 27.5) | (0.7 – 23.5) | (4.0 – 21.7) |
| SS | 18.5 ± 5.7 | 27.0 ± 8.7 | 5.2 ± 2.5 |
| | (7.8 – 27.5) | (8.3 – 45.0) | (1.9 – 10.1) |

* See Figure 1 for locations.
† Based on unweighted monthly data from July 1980 to November 1981 adjusted for a 1-year interval.
‡ Based on unweighted monthly data from July 1980 to September 1981 adjusted for a 1-year interval.

River discharge was relatively low at upstream sites (Table 1), with higher flows usually recorded downstream. In the San Joaquin River, discharge increased at SJR-2 mainly due to inflow from the Delta-Mendota Canal. However, discharge was reduced at SJR-3 because of diversions for irrigation. Between SJR-3 and SJR-6, mean discharge increased with inputs from Salt Slough, the Merced River, and other tributaries.

Mean dissolved oxygen concentrations in the San Joaquin River (Table 2) reached a maximum at SJR-3 (11.9 mg/l, 132% saturation), then gradually declined downstream to SJR-6 (8.0 mg/l, 85% saturation). Mean dissolved oxygen levels in the Merced River were relatively high at both MR-1 and MR-2 (9.8 mg/l and 97% saturation, and 9.3 mg/l and 100% saturation, respectively). Oxygen concentrations averaged 8.1 mg/l (92% saturation) in Salt Slough.

Mean hydrogen-ion concentrations (pH's) at all sampling sites ranged from 7.8 to 8.3, with no apparent longitudinal pattern (Table 2). Highest pH was measured at SJR-3, and coincided with supersaturated oxygen conditions.

Total alkalinity concentrations increased considerably from upstream to downstream sites in both the San Joaquin and Merced rivers (Table 2). In the San Joaquin River, alkalinity reached a maximum at SJR-3. The alkalinity at Salt Slough was intermediate between concentrations measured at SJR-3 and SJR-4.

Conductivities were lowest at upstream sites, and increased downstream (Table 2). In the San Joaquin River, mean conductivity increased more than 30-fold between SJR-1 and SJR-4, then decreased by nearly one-half at SJR-6. Conductivities in the Merced River increased only fourfold from MR-1 to MR-2. Conductivity at Salt Slough was usually higher than elsewhere.

**TABLE 2. Dissolved Oxygen, pH, Total Alkalinity, and Conductivity in the San Joaquin and Merced Rivers, and Salt Slough (mean ± SD; ranges in parentheses).**

| *Site** | *Dissolved oxygen (mg/l)* † | *pH* †,‡ | *Total alkalinity (mg/l $CaCO_3$)* † | *Conductivity (μmhos/cm at 25 °C)* † |
|---|---|---|---|---|
| SJR-1 | 10.4 ± 0.8 | 7.8 | 20 ± 4 | 57 ± 11 |
| | (9.1 – 12.2) | (7.6 – 8.5) | (12 – 30) | (31 – 84) |
| SJR-2 | 10.3 ± 2.3 | 8.0 | 89 ± 14 | 637 ± 172 |
| | (7.4 – 16.3) | (7.7 – 8.4) | (60 – 117) | (300 – 900) |
| SJR-3 | 11.9 ± 3.5 | 8.3 | 176 ± 58 | 1,107 ± 506 |
| | (3.9 – 18.5) | (8.0 – 8.9) | 59 – 262) | (390 – 2,000) |
| SJR-4 | 9.5 ± 1.4 | 8.1 | 167 ± 22 | 1,721 ± 348 |
| | (6.4 – 13.5) | (7.8 – 8.6) | (107 – 218) | (760 – 2,427) |
| SJR-5 | 8.9 ± 0.9 | 7.8 | 132 ± 25 | 1,209 ± 447 |
| | (6.9 – 11.0) | (7.0 – 8.1) | (45 – 175) | (265 – 2,050) |
| SJR-6 | 8.0 ± 1.2 | 7.9 | 116 ± 19 | 816 ± 116 |
| | (6.6 – 10.6) | (7.8 – 8.0) | (77 – 140) | (520 – 990) |
| MR-1 | 9.8 ± 0.9 | 7.9 | 20 ± 3 | 49 ± 8 |
| | (7.5 – 11.4) | (7.5 – 8.7) | (14 – 23) | (35 – 60) |
| MR-2 | 9.3 ± 0.9 | 7.9 | 57 ± 15 | 199 ± 56 |
| | (6.9 – 11.2) | (7.3 – 8.7) | (26 – 78) | (75 – 290) |
| SS | 8.1 ± 1.3 | 7.8 | 173 ± 25 | 1,947 ± 517 |
| | (5.0 – 12.1) | (7.6 – 8.0) | (132 – 228) | (1,158 – 2,800) |

* See Figure 1 for locations.
† Based on unweighted monthly data from July 1980 to November 1981 adjusted for a 1-year interval.
‡ Mean pH was calculated from log-transformed data as described by Kinney (1973); the standard deviation of pH could not be calculated by this procedure.

Mean macronutrient concentrations ($NH_3-N$, $NO_3+NO_2-N$, total N, ortho-$PO_4$, total P) typically increased, upstream to downstream (Table 3). In the San Joaquin River, macronutrient concentrations increased rapidly from SJR-1 to SJR-4, decreased at SJR-5, then increased slightly at SJR-6. (Macronutrient data for SJR-3 were omitted from this analysis because collections were made only in July and October 1980.) In the Merced River, concentrations were highest downstream at MR-2. Concentrations of $NO_3+NO_2-N$ and total N were higher at Salt Slough than at other sampling sites.

Sediments of upstream sites contained a higher percentage of large diameter particles (i.e., pebbles and rocks) than downstream sites (Table 4). Sand, gravel, and pebbles made up most of the sediments at SJR-1 and MR-1; silt and sand were dominant further downstream.

## Distribution and Abundance of Fishes

A total of 43,605 fish representing 33 species (excluding hybrid sunfish, *Lepomis*) and 14 families was collected by combined gear types during this study (Table 5). In the San Joaquin River, the number of species captured at each site ranged from 17 at SJR-3 to 26 at SJR-5 (Table 5). Native species ranged from two at SJR-3 to six at both SJR-1 and SJR-5. In the Merced River, 20 species were caught at MR-1 and 22 species at MR-2. Native fishes totalled seven at MR-1 and six at MR-2. Salt Slough contained 18 species, only one of which was native.

The total numbers of species captured at each of the nine sites were not significantly different ($X^2 = 3.55$, d.f. $= 8$, $P > 0.05$). Furthermore, the proportions of native to introduced species were not significantly different when compared among the various sites ($X^2 = 8.16$, d.f. $= 8$, $P > 0.05$); however, native species generally comprised a larger percentage of the total taxa at the two upstream sites (30% at SJR-1, 35% at MR-1) than at the seven downstream sites (6% at Salt Slough, 12% at SJR-3, 16% at SJR-2, 17% at SJR-4, 19% at SJR-6, 23% at SJR-5, 27% at MR-2).

The fish communities at the various sites were compared by calculating Jaccard's species similarity index. If indices $\geq$ 0.65 are arbitrarily assumed to be significant, then 15 pairs of similar sites were observed (Table 6). The data showed that the two upstream sites (SJR-1 and MR-1) contain a higher proportion of the same species than when each is compared with downstream sites. Furthermore, except for MR-2, the downstream sites shared more species among themselves than with upstream sites. The fish community at MR-2, however, was not significantly similar to communities from either the upstream or other downstream sites.

Several species were captured primarily or exclusively at upstream sites (e.g., sculpins, green sunfish, redear sunfish, Sacramento squawfish, hardhead, and threespine stickleback); other species were captured only at downstream sites (e.g., inland silverside, white crappie, threadfin shad, fathead minnow, splittail, Sacramento blackfish, tule perch, and striped bass) (Table 5). Anadromous chinook salmon were observed from October through April only in the Merced River.

Although catch statistics were influenced by gear selectivity, general trends in the data (Table 5) indicated that the most abundant species at SJR-1 and MR-1 were Sacramento sucker, *Catostomus occidentalis;* green sunfish; bluegill, *Lepomis macrochirus;* redear sunfish; largemouth bass, *Micropterus salmoides;* sculpins; and Sacramento squawfish. Hardhead was abundant at MR-1 but rare at

**TABLE 3. Macronutrient Concentrations in the San Joaquin and Merced Rivers, and Salt Slough (mean ± SD; ranges in parentheses).**

| Site * | $NH_3-N$ (μg/l) | $NO_3+NO_2-N$ (μg/l) | Total N (μg/l) | $Ortho-PO_4$ (μg/l) | Total P (μg/l) |
|---|---|---|---|---|---|
| SJR-1 | 48.5 ± 36.7 | 135.3 ± 127.6 | 303.1 ± 169.3 | 13.6 ± 14.6 | 36.4 ± 11.5 |
| | (6.7 – 99.7) | (3.9 – 313.5) | (94.4 – 519.5) | (1.4 – 32.5) | (21.5 – 47.5) |
| SJR-2 | 36.7 ± 13.4 | 803.9 ± 301.0 | 995.2 ± 233.1 | 118.1 ± 24.3 | 185.4 ± 52.9 |
| | (16.8 – 71.0) | (474.3 – 1,142.1) | (744.6 – 1,303.7) | (97.1 – 148.8) | (121.9 – 311.6) |
| SJR-4 | 315.1 ± 433.2 | 1,848.6 ± 1,049.1 | 1,899.2 ± 712.3 | 213.9 ± 126.4 | 235.9 ± 32.7 |
| | (57.2 – 979.2) | (289.2 – 2,701.1) | (636.5 – 2,686.8) | (60.1 – 399.2) | (143.9 – 291.3) |
| SJR-5 | 70.7 ± 74.6 | 1,512.5 ± 822.5 | 1,536.5 ± 668.6 | 166.5 ± 74.2 | 193.2 ± 60.9 |
| | (12.9 – 179.5) | (373.2 – 2,496.7) | (530.9 – 2,921.5) | (76.0 – 250.4) | (104.2 – 276.7) |
| SJR-6 | 141.5 ± 143.2 | 1,624.4 ± 430.2 | 1,759.5 ± 610.8 | 182.5 ± 47.3 | 234.1 ± 75.1 |
| | (7.0 – 320.4) | (1,016.7 – 2,017.9) | (1,062.5 – 2,481.9) | (123.1 – 230.2) | (146.3 – 323.0) |
| MR-1 | 10.8 ± 7.1 | 34.7 ± 18.4 | 144.1 ± 44.2 | 5.1 ± 6.0 | 30.6 ± 10.2 |
| | (3.1 – 17.5) | (6.0 – 57.1) | (86.1 – 201.3) | (0.0 – 13.5) | (18.4 – 51.2) |
| MR-2 | 111.9 ± 64.8 | 1,448.0 ± 170.9 | 1,525.8 ± 284.1 | 70.3 ± 47.2 | 119.6 ± 41.5 |
| | (27.9 – 326.4) | (1,196.5 – 1,589.5) | (1,102.0 – 1,951.9) | (22.9 – 135.7) | (87.8 – 181.7) |
| SS | 152.6 ± 46.9 | 1,918.7 ± 918.2 | 1,943.8 ± 522.0 | 155.3 ± 81.8 | 220.8 ± 116.1 |
| | (84.8 – 214.1) | (730.5 – 2,962.3) | (1,231.1 – 2,682.5) | (69.7 – 255.3) | (69.2 – 364.2) |

* See Figure 1 for locations.

**TABLE 4. Average Sediment Size Distribution in the San Joaquin and Merced Rivers, and Salt Slough.***

| | Site † | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Particle size | SJR-1 | SJR-2 | SJR-3 | SJR-4 | SJR-5 | SJR-6 | MR-1 | MR-2 | SS |
| Silt, <0.05 mm | 3.8 | 1.5 | 14.1 | 3.8 | 2.1 | 5.9 | 4.1 | 2.2 | 8.8 |
| Sand, 0.05—2.0 mm | 67.0 | 95.3 | 85.3 | 95.7 | 89.4 | 93.9 | 73.9 | 97.6 | 87.4 |
| Gravel, 2.0—9.5 mm | 18.3 | 3.2 | 0.6 | 0.5 | 8.1 | 0.2 | 4.0 | 0.2 | 3.8 |
| Pebble, 9.5—31.5 mm | 11.0 | <0.1 | 0.0 | <0.1 | 0.4 | 0.0 | 13.5 | 0.0 | 0.1 |
| Rock, >31.5 mm | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.6 | 0.0 | 0.0 |

* Values in percent dry-weight.
† See Figure 1 for locations.

**TABLE 5. Occurrence and Relative Abundance of Fishes in the San Joaquin and Merced Rivers, and Salt Slough. Data for Each Sampling Site are Listed as Follows: Bag Seine, Beach Seine, Electrofishing, [a,b,c,d]**

| | Sampling sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Taxon* | *SJR-1* | *SJR-2* | *SJR-3* | *SJR-4* | *SJR-5* | *SJR-6* | *MR-1* | *MR-2* | *SS* |
| Atherinidae | | | | | | | | | |
| Inland silverside, I | O,O,O | R,C,— | A,R,— | A,C,— | A,R,— | A,R,— | O,O,O | A,O,R | A,O,— |
| Catostomidae | | | | | | | | | |
| Sacramento sucker, N | R,O,C | O,O,— | O,O,— | O,O,— | C,R,— | R,O,— | C,O,A | O,O,R | O,O,— |
| Centrarchidae | | | | | | | | | |
| Green sunfish, I | C,A,A, | C,O,— | R,R,— | R,R,— | C,R,— | R,R,— | O,O,A | C,O,C | R,R,— |
| Warmouth (*Lepomis gulosus*), I | O,R,R | R,R,— | O,O,— | R,R,— | R,R,— | O,O,— | O,O,C | R,O,R | R,O,— |
| Bluegill sunfish, I | A,A,A | A,A,— | A,C,— | A,A,— | C,C,— | A,A,— | A,A,A | A,C,A | R,R,— |
| Redear sunfish, I | A,A,C | C,A,— | R,R,— | R,R,— | O,R,— | R,C,— | R,A,C | A,O,R | O,O,— |
| Smallmouth bass (*Micropterus dolomieui*), I | O,O,O | O,O,— | O,O,— | O,O,— | O,O,— | O,O,— | C,O,C | O,O,R | O,O,— |
| Largemouth bass, I | A,A,A | A,C,— | C,C,— | C,C,— | C,C,— | R,C,— | C,C,C | A,C,C | R,O,— |
| White crappie, I | O,O,O | R,R,— | R,R,— | R,R,— | R,R,— | R,C,— | O,O,O | O,O,O | R,O,— |
| Black crappie, I | C,C,R | C,C,— | R,C,— | A,C,— | C,C,— | R,A,— | O,C,O | C,A,C | R,O,— |
| Clupeidae | | | | | | | | | |
| Threadfin shad, I | O,O,O | C,A,— | A,A,— | C,A,— | C,A,— | C,A,— | O,O,O | R,A,C | C,A,— |
| Cottidae | | | | | | | | | |
| Sculpin, N | R,O,C | R,O,— | O,O,— | R,O,— | O,O,— | O,O,— | R,O,A | O,O,R | O,O,— |
| Cyprinidae | | | | | | | | | |
| Goldfish (*Carassius auratus*), I | O,O,R | R,A,— | O,R,— | R,R,— | R,C,— | O,C,— | O,O,O | O,O,C | R,C,— |
| Common carp (*Cyprinus carpio*), I | O,O,R | R,C,— | R,R,— | R,C,— | R,C,— | R,C,— | O,O,R | R,O,C | R,A,— |
| Hitch, N | O,O,O | R,C,— | R,R,— | O,R,— | R,R,— | R,R,— | R,O,R | R,C,R | O,O,— |
| Hardhead, N | O,O,R | O,O,— | O,O,— | O,O,— | O,O,— | O,O,— | A,O,C | O,O,O | O,O,— |
| Golden shiner (*Notemigonus crysoleucas*), I | A,O,C | C,R,— | O,O,— | R,R,— | R,R,— | R,R,— | O,O,O | R,O,R | O,O,— |
| Red shiner (*Notropis lutrensis*), I | O,O,O | R,O,— | O,O,— | O,O,— | O,O,— | O,O,— | O,O,O | O,O,O | O,O,— |
| Fathead minnow, I | O,O,O | A,A,— | C,O,— | C,R,— | A,R,— | C,O,— | O,O,O | O,O,O | A,C,— |
| Splittail, N | O,O,O | O,O,— | O,O,— | O,O,— | R,O,— | O,O,— | O,O,O | O,O,O | O,O,— |
| Sacramento squawfish, N | R,O,C | O,O,— | O,O,— | O,O,— | R,R,— | O,O,— | A,O,A | O,O,O | O,O,— |
| Sacramento blackfish, N | O,O,O | R,R,— | R,C,— | R,A,— | A,A,— | C,A,— | O,O,O | O,C,O | R,A,— |
| Embiotocidae | | | | | | | | | |
| Tule perch, N | O,O,O | O,R,— | O,O,— | R,O,— | R,R,— | O,R,— | O,O,O | O,O,O | O,O,— |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Gasterosteidae | | | | | | | | | |
| Threespine stickleback, N | O,O,R | O,O,— | O,O,— | O,O,— | O,O,— | O,O,— | O,O,O | O,O,O | O,O,— |
| Ictaluridae | | | | | | | | | |
| White catfish (*Ictalurus catus*), I | O,O,C | C,O,— | O,O,— | R,R,— | R,R,— | O,O,— | R,O,R | R,O,C | R,C,— |
| Black bullhead (*Ictalurus melas*), I | R,R,R | R,R,— | O,O,— | R,A,— | R,A,— | O,R,— | O,O,R | O,O,O | C,C,— |
| Brown bullhead (*Ictalurus nebulosus*), I | R,O,R | R,C,— | O,O,— | R,R,— | R,O,— | O,O,— | R,O,R | O,O,O | O,O,— |
| Channel catfish (*Ictalurus punctatus*), I | O,O,O | R,R,— | O,R,— | O,R,— | O,R,— | O,R,— | O,O,O | O,O,R | R,R,— |
| Percichthyidae | | | | | | | | | |
| Striped bass, I | O,O,O | R,R,— | R,O,— | R,R,— | R,R,— | R,R,— | O,O,O | O,O,O | R,R,— |
| Percidae | | | | | | | | | |
| Bigscale logperch (*Percina macrolepida*), I | R,O,R | R,R,— | C,R,— | C,R,— | R,O,— | O,R,— | O,O,C | C,O,C | R,O,— |
| Petromyzontidae | | | | | | | | | |
| Lamprey, N | O,O,C | O,O,— | O,O,— | O,O,— | O,O,— | O,O,— | O,O,C | R,O,R | O,O,— |
| Poeciliidae | | | | | | | | | |
| Mosquitofish, I | C,O,A | A,C,— | A,R,— | A,R,— | A,R,— | A,O,— | C,O,C | A,O,A | A,R,— |
| Salmonidae | | | | | | | | | |
| Chinook salmon, N | O,O,O | O,O,— | O,O,— | O,O,— | O,O,— | O,O,— | O,C,C | O,O,R | O,O,— |

[a] Codes: A = abundant, C = common, R = rare, O = not captured, — = no data, I = introduced species, N = native species.
[b] Relative abundance was based on average percentages of monthly catches.
[c] Total catch (number of fish) at each site: SJR-1, 4,180; SJR-2, 1,746; SJR-3, 2,895; SJR-4, 13,737; SJR-5, 5,337; SJR-6, 3,505; MR-1, 2,108; MR-2, 2,631; and SS, 7,466.
[d] See Figure 1 for locations.

**TABLE 6. Jaccard's Species Similarity Indices for Fish from Selected Sites in the San Joaquin and Merced Rivers, and Salt Slough.*,†**

| | *SJR-1* | *SJR-2* | *SJR-3* | *SJR-4* | *SJR-5* | *SJR-6* | *MR-1* | *MR-2* | *SS* |
|---|---|---|---|---|---|---|---|---|---|
| SJR-1 | | 0.50 | 0.32 | 0.52 | 0.53 | 0.41 | 0.74 | 0.56 | 0.41 |
| SJR-2 | | | 0.68 | 0.96 | 0.82 | 0.77 | 0.45 | 0.62 | 0.72 |
| SJR-3 | | | | 0.71 | 0.65 | 0.81 | 0.32 | 0.56 | 0.75 |
| SJR-4 | | | | | 0.85 | 0.80 | 0.47 | 0.64 | 0.75 |
| SJR-5 | | | | | | 0.81 | 0.48 | 0.60 | 0.69 |
| SJR-6 | | | | | | | 0.37 | 0.59 | 0.70 |
| MR-1 | | | | | | | | 0.62 | 0.36 |
| MR-2 | | | | | | | | | 0.54 |
| SS | | | | | | | | | |

* See Figure 1 for locations.
† Calculations exclude hybrid sunfish.

SJR-1. At MR-2, inland silverside, bluegill, redear sunfish, largemouth bass, black crappie, *Pomoxis nigromaculatus,* threadfin shad, and mosquitofish, *Gambusia affinis*, were abundant (Table 5). The remaining locations (i.e., SJR-2, SJR-3, SJR-4, SJR-5, SJR-6, and Salt Slough) showed some variability in the relative abundance of fishes. In general, the most abundant species at downstream sites were inland silverside, bluegill, largemouth bass, black crappie, threadfin shad, fathead minnow, and mosquitofish (Table 5). Sacramento blackfish was common or abundant at all downstream sites except SJR-2, where it was rarely captured. All Centrarchidae were rare or never captured at Salt Slough even though several species (e.g., bluegill, largemouth bass, black crappie, and redear sunfish) were common or abundant at one or more of the other downstream sites.

## DISCUSSION

Environmental modifications resulting from drainage of agricultural lands may influence aquatic biota (Campbell and Whitley 1970, Dance and Hynes 1980, Hill 1976, Marsh and Waters 1980, Mitchell 1975), including fish (Luey and Adelman 1980). The present study documented several physical and chemical changes at sampling sites on the irrigated San Joaquin Valley floor that generally coincided with changes in fish species composition and relative abundance of individual species.

Except for reduced discharge resulting from storage and diversion of water at reservoirs in the Sierra Nevada foothills (e.g., Millerton Lake on the San Joaquin River; Lake McClure on the Merced River), environmental conditions at the farthest upstream sampling sites (SJR-1 and MR-1) were relatively unaffected by irrigation activities. Turbidity, total alkalinity, conductivity, and macronutrient concentrations were usually low, and dissolved oxygen concentrations were always near saturation.

According to the Jaccard index, fish communities at the two upstream sites were more similar to each other than to communities at downstream sites. Native fishes typical of upstream sites (e.g., Sacramento sucker, Sacramento squawfish, hardhead, threespine stickleback) are usually most abundant in clear, relatively undisturbed streams of the Sierra Nevada foothills, where introduced fishes are rare or absent (Moyle 1976, Moyle and Nichols 1973). Hardhead and threespine stickleback were captured only from upstream sites during this study, even though Moyle (1973) indicated that their original ranges included the

Sierra foothills, Valley floor, and Sacramento-San Joaquin Delta. Moyle *et al.* (1982) suggested that high turbidity may restrict both squawfish and threespine stickleback from low-elevation sites in the Sacramento-San Joaquin drainage system. The most abundant introduced species at upstream sites (i.e., redear sunfish, green sunfish, bluegill, largemouth bass) prefer clear water with aquatic vegetation, and with bottoms of silt, sand, or gravel (Carlander 1977, Moyle 1976, Trautman 1957), although green sunfish are also abundant in turbid, muddy-bottomed environments that have been extensively modified by human disturbances (Moyle 1976, Moyle and Nichols 1973).

In the San Joaquin River, most of the water stored at Millerton Lake is transported southward to Kern County by the Friant-Kern Canal, with a small amount moved north to Madera County by the Madera Canal. Water users downriver in Fresno, Merced, and Stanislaus counties now receive a replacement supply of poorer quality water (i.e., higher in turbidity and conductivity) from the Delta-Mendota Canal (which transports water from the Sacramento-San Joaquin Delta near Tracy, San Joaquin County) at Mendota Pool (California Department of Water Resources 1969), located about 15 km above SJR-2. Water in the Delta-Mendota Canal is initially derived mainly from the Sacramento River basin, but receives irrigation return flows and storm runoff at numerous points along its 190-km length (California Department of Water Resources 1960). Even with this supplemental water, withdrawals during the irrigation season still occasionally eliminate surface flows in the portions of the lower San Joaquin River between Mendota Pool and the confluence with the Merced River (Hazel *et al.* 1976).

Irrigation return flows compensate for some of the river water withdrawn for irrigation below Mendota Pool. However, return flows usually have physical and chemical characteristics much different from the supply water (Hotes and Pearson 1977; Law and Skogerboe 1972; Tanji *et al.* 1977*a,* 1977*b* ). The turbid, saline, and nutrient-rich water environment that characterizes Salt Slough results from its function as a drain for irrigation return flows. In downstream areas of the San Joaquin River (e.g., SJR-3 and 4) where return flows from Salt Slough and other point and nonpoint sources constitute the greatest proportion of total river flow, physical and chemical conditions deviate the most from initial conditions recorded upstream at SJR-1.

The influence of irrigation activities (including return flows) is much less pronounced in the Merced River than in the San Joaquin River. In a previous investigation by the U.S. Geological Survey, Sorenson and Hoffman (1981) concluded that even though some chemical changes occur in the lower reaches from return flows, water in the Merced River is generally of high quality. Inflow of high quality water from the Merced River into the San Joaquin River is reflected in slightly improved conditions (i.e., lower temperature, pH, conductivity, turbidity, and total alkalinity and lower macronutrient concentrations) at SJR-5 when compared to SJR-4.

The modified environmental conditions documented at downstream sites are paralleled by considerable changes in the fish faunas. With the exception of MR-2, the Jaccard index showed that downstream sites shared more species among themselves than with upstream sites. Native fishes captured only at downstream sites (i.e., hitch, *Lavinia exilicauda;* Sacramento blackfish; splittail; tule perch) are most abundant in the Sacramento-San Joaquin Delta and tributaries immediately upstream from the Delta (Moyle 1976); however, these popula-

tions may be slowly declining because they are now absent from localities where they were formerly present (Moyle 1973, 1976). According to Moyle (1976), the herbivorous filter-feeding habits of Sacramento blackfish, coupled with their ability to survive in warm, turbid habitats, probably has allowed them to maintain relatively large populations despite changes in their environment. Hitch and splittail also seem to be persisting under the pressures of environmental changes and introductions of exotic predators and competitors. Tule perch, though, are disappearing from streams with reduced flows, increased turbidity, heavy pollution, or reduced cover (Moyle 1976).

Introduced species (i.e., inland silverside, bluegill, largemouth bass, black crappie, threadfin shad, fathead minnow, mosquitofish) were especially abundant at downstream sites. Although these fishes can tolerate turbid, brackish, nutrient-rich environments, several species (i.e., bluegill, largemouth bass, black crappie) prefer clear, fresh water with abundant beds of submerged aquatic vegetation (Carlander 1977, Moyle 1976, Trautman 1957). Other species (e.g., fathead minnow, mosquitofish) are able to produce large populations over a broad range of environmental conditions as long as predatory fishes and competitors are rare or absent (Moyle 1976, Trautman 1957). Fathead minnow seemed to be especially abundant in Salt Slough where piscivorous largemouth bass and black crappie were rarely caught.

The downstream environment at MR-2 was degraded somewhat from conditions at MR-1, but not to the extent exhibited by downstream sites on the San Joaquin River and Salt Slough. The site at MR-2 also contained a fish fauna composed of species characteristic of both upstream and downstream sites. The most abundant species (i.e., bluegill and mosquitofish) were also generally abundant at other locations. Sacramento sucker, redear sunfish, and green sunfish (typical of upstream sites), and inland silverside, threadfin shad, and Sacramento blackfish (typical of downstream sites) were all captured at MR-2. These data suggest that MR-2 represents a transitional habitat containing environmental and fish faunal elements of both upstream and downstream sites.

This study shows that irrigation activities have modified the physical and chemical environment of low elevation rivers on the San Joaquin Valley floor, and that the modifications have probably influenced the composition and abundance of fish faunas. However, there is still a great need for further investigations that identify the toxic components of irrigation return flows and measure their effects on the survival, growth, reproduction, and behavior of fishes. Inasmuch as food availability, predation, competition, and other biological factors can influence fishes, these interactions must also be studied. Such research would help to establish more clearly the magnitude of impacts of return flows on fishes and enable more objective decisions to be made on the merits of future irrigation drainage projects.

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# RELOCATION OF ORIGINAL TERRITORIES BY DISPLACED BLACK-AND-YELLOW ROCKFISH, *SEBASTES CHRYSOMELAS*, FROM CARMEL BAY, CALIFORNIA [1]

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**The black-and-yellow rockfish, *Sebastes chrysomelas*, is a perennially territorial species that normally exhibits limited movement away from its territory. A total of thirty individuals were transported away from their territories during four translocation experiments. A high percentage (66%–71%) of fish returned to the site of capture within two weeks, from distances up to 50 meters. Fish moved 1.5 kilometers from their territories did not return, even after 4 months. Sensory parameters used by this species for territory relocation are unknown. Homing behavior in a normally sedentary species seems paradoxical, and this species may be more mobile than previously thought.**

## INTRODUCTION

Reports of manipulations used to induce homing behavior and studies of natural homing behavior among salmonid fishes are too numerous to list. However, the homing phenomenon has not been so widely studied among other groups of fishes. Williams (1957) discusses possible homing behavior by fishes inhabiting the tidal zones of California. Green (1971) reports that a high percentage of the tidepool sculpin, *Oligocottus maculosus*, return to specific tidepools with the incoming tide after leaving with the outgoing tide. Clarke (1970) in his work on the garibaldi, *Hysypops rubicunda*, observed that adult males returned to their territories after moving off them to forage.

Homing by fishes of the genus *Sebastes* has been examined by a few workers. Miller and Geibel (1973) reported seasonal movements by the blue rockfish, *S. mystinus*, and suggested that local populations may return to specific kelp forests. Carlson and Haight (1972) demonstrated that the yellowtail rockfish, *S. flavidus*, can return to its home site over distances of 22.5 km even after 3 months in captivity.

Both *S. mystinus* and *S. flavidus* are nonterritorial, aggregating species. Would a territorial species of rockfish, normally exhibiting limited movement away from its territory, home if displaced from that territory? This study was designed to determine if the black-and-yellow rockfish, *S. chrysomelas*, a territorial species, could locate its home site if artificially displaced, and to ascertain if individual fish would reoccupy the specific territory from which they were removed.

## MATERIALS AND METHODS

Translocation manipulations were carried out between July 1975 and December 1976 in Carmel Bay, California. Fish were captured underwater by a diver dangling a baited hook in front of them. They were tagged with plastic floy tags and the holes from which fish were removed were marked with numbered lead markers. Fish were measured, placed in a canvas bag, and moved to the release

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site. The fabric weave of the canvas bag used for transport of fish was tight, preventing the fish from seeing out during the translocation process, and probably inhibiting water currents through the bag. The entire translocation process was done using Scuba without bringing fish to the surface, except on one long-distance translocation where fish were brought to the surface and transported by boat. Gas bladder damage to fish brought to the surface was reduced by inserting a hypodermic needle into the gas bladder so that gas could escape.

All manipulations were conducted within inshore *Macrocystis pyrfera* kelp forests. Habitats of capture and release were similar, consisting of level rocky bottom with numerous holes and interstices. Depth of capture and release for each fish were within 1 m of each other. Areas chosen for removal of fish were approximately 25 $m^2$, and ranged in depth from 7 to 12 m.

Three short translocations were conducted over the distances of 25, 40, and 50 m. Nine fishes, which were not measured but were adults, were displaced on the 25 m translocation, and the home and release sites were checked 3 times over 21 days (Table 1). Seven fishes, ranging in size from 180–300 mm TL, were displaced on the 50 m translocation, and the home and release sites were checked 7 times over 326 days (Table 1). Seven fishes, ranging in size from 200–280 mm TL, were displaced on the 40 m translocation and the home and release sites were checked 6 times over 43 days (Table 1). In the 25 and 50 m translocations, none of the territorial residents in the release area were removed. In the 40 m translocation, all territorial fish occupying the release area were removed by spearing before translocated fish were released. Eight *S. chrysomelas*, ranging in size from 180–290 mm TL, were removed. The gopher rockfish, *S. carnatus*, which is also territorial, was not seen on the release site.

On the long-distance translocation, seven fishes ranging in size from 200–305 mm TL, were moved to a different kelp forest within Carmel Bay. The direct distance separating the home site (Carmel Point—Butterfly House) and the release area (Point Lobos State Reserve) was approximately 1.5 km, while I estimate the distance by coastline to be about 10 km. The home and release sites were checked five times over 123 days.

## RESULTS

A high percentage of translocated black-and-yellow rockfish returned to their home sites after being moved 25, 40 and 50 m (Figure 1). Of nine individuals moved 25 m, a total of six were sighted on the 25 $m^2$ grid area after 13 days, with three being seen at least one time in the holes from which they were captured (Table 1). Three of the individuals translocated 25 m were not resighted, either on the home site or in the release area. Five of the seven fish moved 40 m were resighted on the home site after 8 days, with all five being seen at least one time in their original holes. On the 50 m translocation, five of the seven fish moved were resighted on the home site after 11 days, with all five being found in their original holes (Table 1). On both the 40 m and 50 m translocations, two of the fish were not resighted.

None of the seven individuals moved 1.5 km were observed on the home site during 5 checks of the area over a period of 3 months (Figure 1). As in the shorter translocations, each time the home site was checked on this long-distance translocation, the release area was also inspected. None of the tagged fish were seen.

**TABLE 1. Resightings of Previously Translocated Fish on Their Original Home Sites Are Listed. Day Values Represent Time Elapsed Between the Site Check and the Translocation Date. Meter Designations Represent the Distance That a Resighted Fish Was From Its Original Hole. Distances for Individuals Seen in Their Original Holes Are Listed As 0 m. Individuals Not Sighted During a Particular Check of the Home Site Are Denoted by Dashes (—).**

25m Translocation
29 August 1975

| *Specimen No.* | *Size* | *Check 1* *6 days* | *Check 2* *13 days* | *Check 3* *21 days* |
|---|---|---|---|---|
| 1 | — | — | 1.2 m | 1.8 m |
| 2 | — | — | 1.5 m | — |
| 3 | — | — | — | — |
| 4 | — | — | 3.5 m | — |
| 5 | — | — | — | — |
| 6 | — | — | — | — |
| 7 | 300mm * | 0 m | 2.1 m | — |
| 8 | 300mm * | 0 m | 1.8 m | — |
| 9 | 180mm * | 0 m | — | — |

* Size estimated.

40m Translocation
24 August 1976

| *Specimen No.* | *Size* | *Check 1* *1 day* | *Check 2* *7 days* | *Check 3* *8 days* | *Check 4* *9 days* | *Check 5* *13 days* | *Check 6* *43 days* |
|---|---|---|---|---|---|---|---|
| 1 | 250mm | — | 0.3 m | 0 m | — | — | 1.2 m |
| 2 | 250mm | — | — | — | — | — | — |
| 3 | 200mm | — | — | — | — | — | — |
| 4 | 280mm | — | — | 0 m | — | — | — |
| 5 | 270mm | 1.8 m | 3.5 m | 3.5 m | 3.5 m | 3.5 m | 3.5 m |
| 6 | 240mm | 0.3 m | — | — | — | — | 0.3 m |
| 7 | 280mm | 0 m | — | — | — | 0 m | 0 m |

50m Translocation
12 September 1975

| *Specimen No.* | *Size* | *Check 1* *7 days* | *Check 2* *10 days* | *Check 3* *11 days* | *Check 4* *12 days* | *Check 5* *306 days* | *Check 6* *310 days* | *Check 7* *326 days* |
|---|---|---|---|---|---|---|---|---|
| 1 | 315mm | — | 0 m | 0 m | — | — | — | — |
| 2 | 270mm | 0.9 m | 0 m | 0 m | 0 m | — | — | 2.0 m |
| 3 | 215mm | — | — | 0 m | — | — | — | — |
| 4 | 300mm | — | — | 0 m | 0 m | — | — | — |
| 5 | 300mm | 0 m | 0 m | 0 m | — | 0.3 m | 0 m | — |
| 6 | 180mm | — | — | — | — | — | — | — |
| 7 | 250mm | — | — | — | — | — | — | — |

The removal of territorial residents from the 40 m translocation release area did not alter homing behavior. The same percentage of fish returned from this release area, as from the 50 m release area where resident territorial fish were not removed.

The time required for displaced fish to return to the home site appeared to be short. Minutes after their release on the 40 m translocation, two fish were observed about half way between the release area and the home site. Both were swimming close to the bottom in the direction of the area from which they were removed.

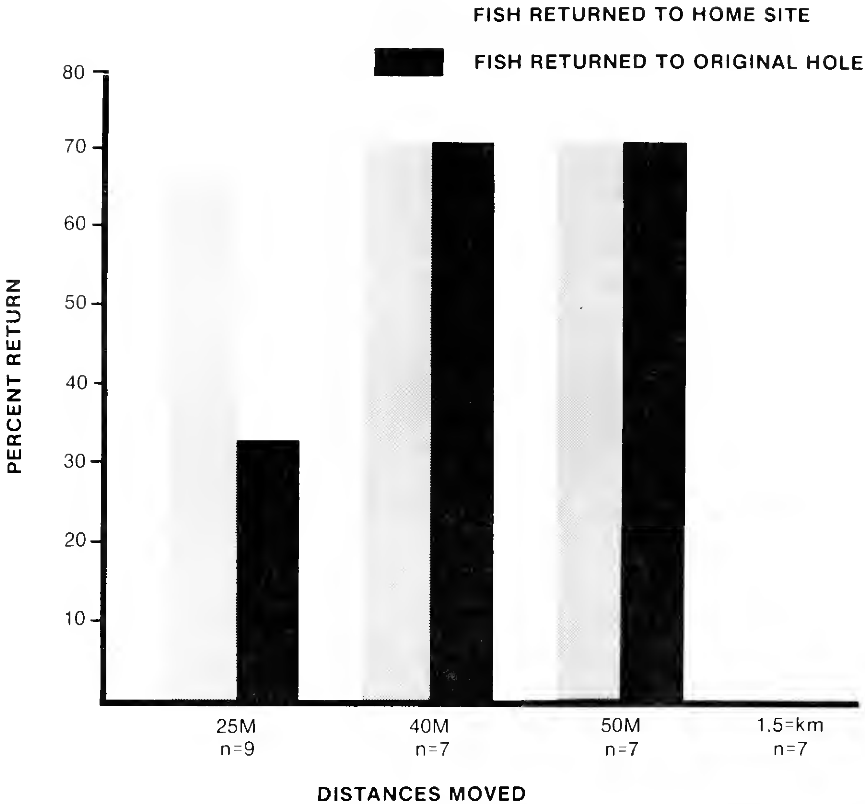


FIGURE 1. Return of *S. chrysomelas* to home sites (open bars) and original holes within home sites (hatched bars) after their translocation to release areas 25m, 40m, 50m, and 1.5 km away from the home site. Columns represent percentage of n fish translocated that returned.

## CONCLUSION

The black-and-yellow rockfish, *S. chrysomelas,* is a territorial species, probably occupying territories on a perennial basis (Hallacher 1977; Larson 1980*a*, *b*). Observations suggest that this species normally remains closely associated with its territory, although Larson (1980*a*) observed individuals, which he referred to as "commuters", that moved up to 20 m on a daily basis. The results of this investigation indicate that a high percentage of *S. chrysomelas* were able to return to their territories when displaced distances of 25 to 50 m, although none were able to return to their home site after being displaced 1.5 km.

The results of the successful translocations raise the interesting question of why a species, apparently perennially sedentary in habit, possesses the ability to home over distances of *at least* 50 m; distances which exceed, by a factor of two, previously reported movements by this species. Black-and-yellow rockfish may, in fact, be more mobile than has been reported, which could result in their familiarity with features of the bottom near their territories, and could explain their short-range homing ability. However, a general knowledge of sur-

rounding bottom topography may be retained from recruitment, and life as a nonterritory holder. This, too, could account for short-range homing in a species normally exhibiting limited extraterritorial movement.

The use of physical parameters other than visual knowledge of local topography may be involved in successful homing by this species. If so, the parameters utilized in relocating the home site are unknown. The use of stimuli such as thermal, or rheotactic clues seems unlikely due to the homogeneous nature of the kelp forest in regard to those parameters. Perhaps territorial residents delineate their home ranges with chemical markers, but this, too, seems unlikely. Identification of the mechanisms utilized by the black-and-yellow rockfish to home, as well as the adaptive significance of this seemingly paradoxical behavior remains to be discovered.

## ACKNOWLEDGMENTS

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# SURGICAL IMPLANTATION OF A RADIOTELEMETRY DEVICE IN WILD BLACK BEARS, *URSUS AMERICANUS*[1]

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**Ten free-roaming black bears, *Ursus americanus*, were implanted surgically with radiotelemetry devices. The devices were implanted subcutaneously, parallel with the spine, in the cervical-scapular region. Three of the 10 implants were rejected and recovered. One implant was recovered when the bear was killed on a depredation permit. The fate of the remaining six implants is uncertain. Mechanical failure, conspecific interactions, and surgical failure are factors that affected the success of this study. Poaching also may have been a factor.**

The advent of radiotelemetry in the late 1960's enabled biologists for the first time to determine movements, habitat utilization patterns, and mortality factors of black bears.

Generally bears are fitted with conventional radiotelemetry collars on all age and sex classes of a typical population. Adult black bears, especially the males, often have neck girths larger than their maximum head girths resulting in slippage and/or removal of the telemetry collar. Because they are still growing, subadult bears can only be fitted with expandable radiotelemetry collars which often are removed easily. Also, the elastic in these collars deteriorates and breaks within six months, a time period too short to follow bears from den emergence in spring to den entry in winter (Koch 1983).

A radiotelemetry device that is surgically implanted can be used on all members of a bear population. Implantable telemetry devices have the added advantage of generating physiologic data such as heart rate, body temperature, and respiration rate.

Prior use of radiotelemetry implants in black bears has met with mixed success. The body location chosen to implant the device appears to be the critical factor. Implanting the device in areas subject to licking and/or scratching have failed in the past. Intra-abdominal implants have resulted in a greatly reduced transmission range (Mike Philo, Institute of Arctic Biology, University of Alaska, Fairbanks, pers. commun.). Due to these problems, we chose to experiment with a subcutaneous location in the cervical and scapular region.

Ten radiotelemetry transmitters designed for surgical implantation were purchased from Telonics, Inc. (932 E. Impala Ave., Mesa, Arizona 85204). The implants each weighed 150 g and were shaped like a small, fat cigar 12.5 cm by 3.5 cm in diameter. The implants were coated with two layers of moisture-impervious resin and paraffin. They transmitted in the 159 MHz range with an

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effected radiated power of 250 mW. All of the transmitters were designed to double their pulse rates when motionless for five or more hours (mortality mode). Additionally, three of the transmitters were designed to vary pulse rate with body temperature, unless overridden by the mortality mode. Prior to implantation, the transmitters had an effective transmission range of 5–8 km. In an attempt to increase this range, the transmitter antenna length was increased by wrapping 00 surgical stainless steel wire around the center of the implant three times. To assure tissue compatibility, the implants were dipped three times in medical grade silicone (Silastic, Dow Chemical Co., P.O. Box 68511, Indianapolis, Indiana 46268) that had been thinned with petroleum ether for easier handling. When dry, the implants were gas sterilized. Four mock-up transmitters with the exact weight, dimensions, and external coatings were prepared for use in laboratory tests to determine the most effective surgical technique and location. Results from four separate implants on two captive bears determined surgical technique later used for ten black bears in the French Meadows area of the Tahoe National Forest.

Bears were captured in culvert traps and immobilized with a 0.02 mg/kg of body weight injection of etorphine (M-99, Drummer Laboratories, 111 Leuning St. South, Hackensack, NJ 07706). When the bears vital signs were stable the implant site was prepared for aseptic surgery. A 15-cm incision was made along the dorsal mid-line over the last two cervical vertebrae. Subcutaneous tissues were bluntly separated and the dermal shield was incised. The insertion and aponeurosis of the trapezius muscles were located and incised, exposing the rhomboideus muscles. A bed for the implant was prepared between the left and right rhomboideus muscles and the implant slipped into place. As a prophylactic measure, one million units of potassium penicillin were injected around the implant. The stainless steel antenna wires of the device were secured to deep connective tissue and then to one another. The trapezius aponeurosis and the dermal shield were each closed by simple continuous suture pattern of #1 dexon. The skin was closed with a simple interrupted suture pattern of #1 dexon. One million units each of benzathine and procain penicillin (Flo-Cillin, Bristol Laboratories, Syracuse, New York 13201) were administered intramuscularly. After the implant was tested for inplace function, a 0.04 mg/kg of body weight injection of diprenorphine (M50-50, Drummer Laboratories) was given intravenously to reverse the affects of etorphine. Recovery was marked by several rapid respirations, a brief groggy period, then fairly rapid well-coordinated flight. Recovery took from 2–5 minutes.

The healing process was evaluated in only two bears. Bear L8828 was held in captivity after surgery for approximately two months prior to his release in the study area. The healing process was rapid and hair regrowth made it difficult to visually detect the implant one month later. When this animal was killed on a depredation permit 14 months after the implant surgery, the transmitter was accidentally discovered when the bear was skinned. Bear #4890 was recaptured 15 days after surgery. Healing was complete and there was no evidence of post-surgical infection.

The experimental use of radiotelemetry implants during this study was not successful (Table 1). Three of the telemetric devices were either sloughed due to surgical failure, removed by the bear itself, or by another bear. One transmitter was recovered when an implanted bear was killed on a depredation permit. The

remaining six implants were not recovered. These implants functioned for a short time. They either failed, or the bears left the study area.

**TABLE 1. Summary of Results for Ten Radiotelemetry Implants in Free-Roaming Black Bears, Tahoe National Forest, California.**

| *Bear #* | *Sex/Age* | *Implant Date* | *Last Location* | *Number of Locations* | *Comments* |
|---|---|---|---|---|---|
| 4894 | F/5 | 7 July 1979 | 28 Aug 1979 | 23 | Transmitter rejected; recovered in area of heavy bear use. Mated with bear #4892. |
| 4895 | M/2 | 13 July 1979 | 28 Sept 1979 | 16 | Transmitter functioning sporadically from 29 Aug 1979. Transmitter failure or illegal kill. |
| 4897 | F/2 | 16 July 1979 | 7 Aug 1979 | 6 | Suspected transmitter failure or illegal kill. |
| 4896 | F/5 | 16 July 1979 | 20 Aug 1979 | 4 | Transmitter rejected: recovered in area of low bear use. |
| 4892 | M/5 | 11 July 1979 | 21 Aug 1979 | 5 | Suspected transmitter failure or illegal kill. Mated with bear #4894. |
| 4890 | F/7 | 1 July 1979 | 5 Sept 1979 | 11 | Bear recaptured 15 days after implant surgery; implant area completely healed, but transmitter rejected and recovered. |
| 4888 | M/5 | 6 June 1979 | 28 Sept 1979 | 6 | Transmitter functioning sporadically, and not recovered. |
| 4891 | F/7 | 10 July 1979 | 30 July 1979 | 6 | Suspected transmitter failure or illegal kill. |
| 4893 | M/3 | 12 July 1979 | 5 Oct 1979 | 15 | Transmitter shifted to mortality mode; however, bear moved several times after that. Transmitter not recovered. |
| L8878 | M/5 | 10 June 1978 | 23 July 1979 | 14 | Test bear; trapped 15 April 1978, released 10 June 1978. Shot on depredation permit 28 July 1979. Implant recovered. |

The three recovered transmitters all had teeth marks the size, depth, and spread suggesting the canine teeth of a large canivore, probably ursine. These transmitters were free of blood or tissue and one had lost its Silastic coating. There was no evidence of a carcass or a bear kill in the area surrounding the recovered transmitters. It is possible that these three transmitters were removed during breeding activities. Bear #4894 mated with bear #4892 five days after her implant surgery. Bears #4890 and #4896 were adult females in estrus at the time of their implant surgery, so it is likely that they mated after surgery. The possibility of surgical failure in bear #4890 is unlikely as excellent healing was observed 15 days after surgery.

The fate of six unrecovered transmitters remains unknown. Mechanical failure is suspected as two of the implants functioned sporadically before contact was lost. The transmitter in bear #4893 shifted to mortality mode while the bear continued to move throughout the study area. The increase in pulse rate when the transmitter is in mortality mode will greatly reduce the battery life of the transmitter, and this may explain the loss of contact.

Illegal take of black bears is a serious problem throughout California (Piekielek and Burton 1975, Sitton 1982, Koch 1983) and the possibility that transmitters were removed from the study area because of illegal hunting cannot be ruled out. Natural movements out of the study area by implanted bears are not likely as little dispersion was observed by animals fitted with conventional radio-telemetry collars in the same area (Koch 1983). Also, extensive efforts, via fixed-wing aircraft, to locate implanted bears outside of the study area were unsuccessful.

The lack of success in this study should not be attributed solely to the surgical procedure. Mechanical failure, and conspecific activity also contributed to the failure of this experiment. In addition, suspected illegal hunting may have been a factor.

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# SEASONAL VARIATION IN THE DIET OF THE THREESPINE STICKLEBACK, *GASTEROSTEUS ACULEATUS*, IN CONTRA COSTA COUNTY, CALIFORNIA [1]

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**The major food items of threespine stickleback, *Gasterosteus aculeatus*, in Contra Costa County were insects (41.8%), crustacea (27.8%), and earthworms (9.6%). The relative importance of these items changed seasonally, although chironomid larvae formed a large part of the diet throughout most of the year. The percentage of fish with empty stomachs also varied seasonally, with the largest percentage occurring in fall and winter. The existence of schools of females and nonbreeding males may account for conflicting reports concerning differences in feeding behavior between the sexes during the breeding season. These schools may also account for the apparent correlation between food shortage and an increase in nest raiding.**

## INTRODUCTION

The threespine stickleback has a wide distribution across parts of Asia, Europe, and North America (Wootton 1976). In California, it is found in streams along the northern coast and throughout the Central Valley (Bell 1976). Sticklebacks have a large impact on California's waterways, consuming eggs and young of commercially important species and serving as food for predatory fishes and birds (Moyle 1976). The remarkable success of this species is due to a variety of characteristics that enable it to survive in diverse environments. These characteristics include a tolerance for a broad range of salinities and temperatures, morphological and behavioral adaptations to deter predators, and a high degree of care of the young by the male.

Another factor contributing to the success of sticklebacks is opportunistic feeding behavior. Their diet consists of a wide range of items including the larvae and pupae of insects, crustaceans, molluscs, oligochaetes, fish eggs, plant material, and detritus (Wootton 1976). A study of seasonal variation in the diet of stream-dwelling sticklebacks in England showed that the relative importance of food items changed greatly with the season: crustacea were important during the summer, while molluscs and oligochaetes were consumed mainly in winter (Hynes 1950). Chironomid larvae were an exception, forming a major part of the diet in all months.

According to Schoener (1971), differences in feeding behavior should be expected between the sexes. Females generally maximize their reproductive output by increasing the energy spent on egg production and by choosing an optimal mate. In contrast, males generally maximize their reproductive output by choosing appropriate behaviors, such as mating as often as possible or by providing care for their young. The result is often lower energy requirements for males during the breeding season. In sticklebacks, there are conflicting reports regarding feeding differences between males and females. Worgan and Fitzgerald (1981) reported that male sticklebacks feed less frequently than females

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during the breeding season, but Hynes (1950) found no significant differences in feeding habits between the sexes.

Sticklebacks of both sexes commonly raid nests, although males are more often involved than females (Kynard 1978). The widespread occurrence of this behavior among breeding males suggests that it plays an important role in their reproductive process. Nest raiding may increase the attractiveness of the raider to females (Li and Owings 1978, Rohwer 1978), and raiding males may increase their reproductive output by fertilizing the eggs in a rival's nest (Assem 1967). There is evidence that the frequency of nest raiding increases in both sexes if there is a shortage of food (Adalsteinsson 1979). This correlation between the supply of food and the frequency of nest raiding has not been reconciled with theories of nest raiding as a reproductive strategy.

This study provides information on the diet of California sticklebacks and adds to our knowledge of nest raiding and differences in feeding behavior between the sexes.

## STUDY AREA

All specimens were collected from San Pablo Creek, a freshwater drainage in Contra Costa County. Four study sites wre chosen using ease of access and presence of sticklebacks as criteria. They were "Garden," "Park," "Fordham," and "Appian" and were approximately .8, 1.8, 3.5, and 6.0 km from the San Francisco Bay, respectively. The width of the creek ranged from 2.0–3.0 m and the depth from 0.5–1.5 m. The flows increased greatly during periods of heavy rain and flooding occurred at most locations. Water temperature ranged from 9°C in January to 18°C in August. The creek contained sparse vegetation except for emergent grasses (*Phalaris*) and ground ivy (*Hedera*) near the banks.

## METHODS AND MATERIALS

Specimens were collected with a long-handled dipnet monthly from February 1982 to January 1983. They were anesthetized in 0.5% phenoxyethanol, and within minutes transferred to a 10% formalin solution. After 3–4 days they were rinsed and placed in 50% isopropyl alcohol.

For each specimen the following were recorded: body weight, standard length (SL), number of lateral plates, body depth (greatest value), and length of pelvic and dorsal spines. These features separate subspecies of *Gasterosteus.* Sex was determined by the size and color of the gonads: ovaries were large and yellow or white, testes were smaller and gray or black. To assure accurate plate counts and correct determination of sex, only specimens over 30 mm were used.

The composition of the diet was determined by the point system outlined by Hynes (1950). The contents of each stomach were examined within 2 wk following capture and identified as far as possible under a stereoscope. Insects were grouped into pupal, larval, or adult stages. The relative frequency of each food type was estimated visually, and assigned points based on their relative abundance. The points for each category were summed over all individuals to obtain the total diet composition.

## RESULTS

The sticklebacks collected from San Pablo Creek were *Gasterosteus aculeatus microcephalus,* characterized by low plate counts and lack of a caudal keel (Bell 1976). Across ail seasons and sites, 41.8% of the diet was insects (mainly

chironomid larvae), 27.8% was crustacea (mainly ostracods), and 9.6% was earthworms (*Lumbricidae*). Stomachs were empty in 20.7% of the specimens examined (Table 1).

**TABLE 1. Composition of the Diet of Threespine Stickleback from San Pablo Creek, Contra Costa County, California**

| *Food Item* | *Appian* | *Fordham* | *Park* | *Garden* | *All Sites Combined* |
|---|---|---|---|---|---|
| Crustacea | | | | | |
| Ostracoda | 11.5 | 12.2 | 4.5 | 7.5 | 9.0 |
| Other crustacea | 14.9 | 22.3 | 21.5 | 17.0 | 18.8 |
| Insects | | | | | |
| Pupae | 5.7 | 14.4 | 9.8 | 6.7 | 9.2 |
| Chironomid larvae | 16.8 | 18.1 | 18.0 | 28.5 | 20.6 |
| Other larvae | 9.7 | 4.7 | 3.2 | 3.5 | 5.2 |
| Diptera adults | 2.4 | 2.2 | 1.3 | 2.9 | 2.2 |
| Other adults | 5.4 | 5.1 | 3.2 | 4.5 | 4.6 |
| Nematodes | .3 | .5 | 1.2 | .1 | .5 |
| Annelids | | | | | |
| Earthworms | 13.6 | 4.7 | 11.0 | 9.1 | 9.6 |
| Other Annelids | .8 | .4 | .8 | .3 | .5 |
| Fish eggs | 2.0 | 3.0 | 2.2 | 2.3 | 2.4 |
| Plant Material | 2.6 | 1.8 | 12.6 | 9.7 | 6.6 |
| Animal Material | 14.3 | 10.6 | 10.7 | 7.9 | 10.8 |
| Stomachs examined | 167 | 183 | 161 | 175 | 686 |
| Empty stomachs | 33 | 45 | 34 | 30 | 142 |
| Percent empty stomachs | 19.8 | 24.6 | 21.1 | 17.1 | 20.7 |

The diet of the sticklebacks showed pronounced seasonal variation (Figure 1; Table 2). Earthworms were the most common item eaten from February to April, but were absent from the diet from May to October. Insects, especially chironomid larvae, were consumed throughout the year and were the major component of the diet from May to August. Crustaceans were also eaten in most months, and were preyed upon heavily from September to December.

The percentage of fish with empty stomachs varied seasonally, with the highest percentage in winter and the lowest in spring. During the breeding season from February to August, the number of empty stomachs among males (29 out of 134) was significantly higher than among females (24 out of 212) ($X^2 = 5.97$, d.f. $= 1$; $P < .05$).

Evidence of intraspecific egg predation was found in samples collected from May to August. The number of males that had consumed eggs (13 out of 80) was significantly larger that the number of females (6 out of 128) ($X^2 = 6.60$, d.f. $= 1$; $P < .05$). The males involved were over 39 mm SL, the females over 48 mm SL. All of the eggs consumed were fertilized, and eyed embryos were visible.

## DISCUSSION

The seasonal variation in the diet of sticklebacks in San Pablo Creek was similar to that elsewhere (Hynes 1950, Walkey 1967). Chironomid larvae were eaten in large numbers throughout the year, while the importance of other items

varied seasonally. The appearance of earthworms in the diet during the winter may have been a result of high water levels washing the worms out of the soil. A similar occurrence involving terrestrial arthropods was mentioned by Hynes (1950). Seasonal variation in the diet is a reflection of changes in the actual numbers of food items as well as changes in their relative availability.

My results and those of others (Semler 1971, Kynard 1978) indicate that egg predation is more common among male sticklebacks than among females. Breeding males may consume eggs obtained in successful raiding attempts, and there is evidence that males may eat some of their own brood (Rohwer 1978). Other instances of egg predation are probably due to attacks on nests by schools of females and nonbreeding males. These raider packs have been observed to destroy nests and to eat the eggs (Kynard 1978).

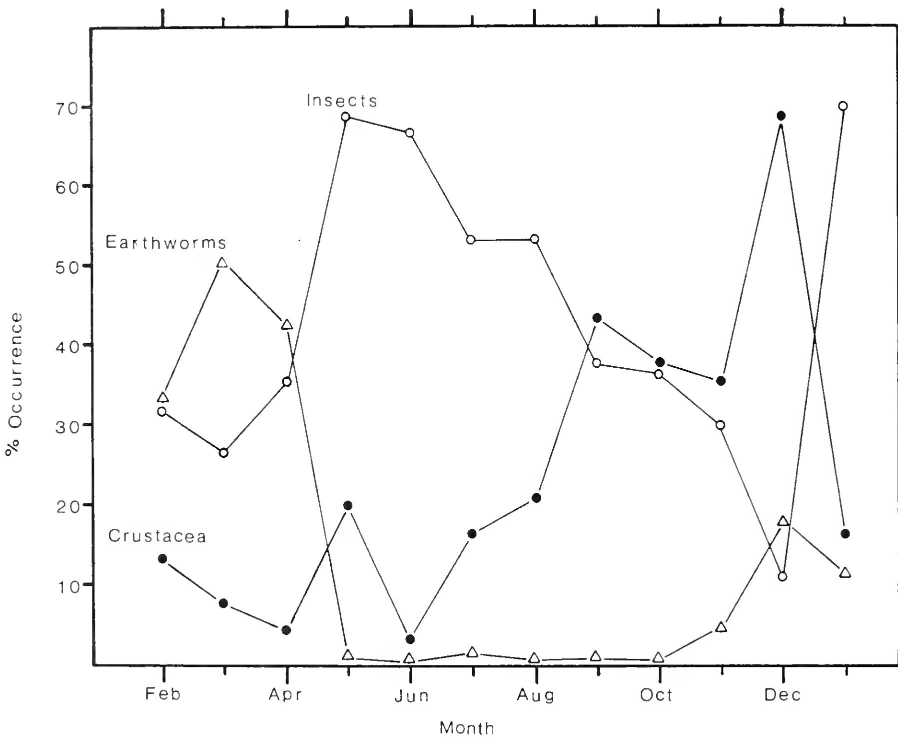


FIGURE 1. Seasonal variation in the consumption of major food groups by threespine stickleback from San Pablo Creek, Contra Costa County, California.

The correlation between food supply and frequency of nest raiding (Adalsteinsson 1979) may be due to increased attacks by raider packs when food is scarce. It is likely that the purpose of these attacks is to obtain food and their frequency would be influenced greatly by food supply. In contrast, nest raiding in breeding males is closely linked to the reproductive process, and therefore not affected by supply of food.

**TABLE 2. Seasonal Variation in the Consumption of Major Food Groups by Threespine Stickleback from San Pablo Creek, Contra Costa County, California (all sites combined)**

| | Percent Composition of Diet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Food Item* | *Feb* | *Mar* | *Apr* | *May* | *Jun* | *Jul* | *Aug* | *Sep* | *Oct* | *Nov* | *Dec* | *Jan* |
| Crustacea | 12.8 | 8.3 | 4.3 | 20.1 | 2.8 | 16.1 | 20.7 | 42.8 | 36.9 | 34.2 | 68.2 | 15.6 |
| Insects | 31.7 | 26.8 | 34.6 | 68.6 | 67.1 | 53.0 | 53.3 | 37.5 | 36.5 | 29.6 | 11.4 | 70.3 |
| Earthworms | 32.3 | 50.0 | 42.1 | .5 | 0.0 | 1.1 | 0.0 | 0.0 | 0.0 | 3.6 | 16.8 | 10.9 |
| Stomachs examined | 56 | 30 | 52 | 53 | 23 | 48 | 84 | 80 | 80 | 80 | 72 | 28 |
| Empty stomachs | 15 | 9 | 17 | 0 | 1 | 3 | 8 | 14 | 15 | 31 | 17 | 12 |
| Percent empty stomachs | 26.8 | 30.0 | 32.7 | 0.0 | 4.2 | 6.3 | 9.5 | 17.5 | 18.8 | 38.8 | 23.6 | 42.9 |

My results support the observation of Worgan and Fitzgerald (1981) that breeding males feed less often than females. Insufficient data were collected in the present study to provide a comparison between feeding behavior of breeding and nonbreeding males. However, the observations of Kynard (1978) strongly suggest that nonbreeding males continue to feed throughout the breeding season, in contrast to the infrequent feeding in breeding males. This difference in feeding behavior accounts for the results of Hynes (1950), which show no significant differences in feeding behavior between the sexes. If the samples collected by Hynes contained a large proportion of nonbreeding males, then the infrequent feeding of breeding males might have been overlooked.

Although much is known about the general feeding habits of sticklebacks, there is more to be learned about their feeding behavior during the breeding season. Controlled experiments in the laboratory could test the hypothesis that nest raiding in breeding males is independent of the food supply. In addition, a careful analysis of specimens collected from the field might give further support to the claim that breeding males feed less frequently than females and nonbreeding males.

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# ATTACKS ON DIVERS BY WHITE SHARKS IN CHILE [1]

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**Three attacks upon divers in Chile are reported, analyzed, and illustrated. Attacks at El Panul on 29 September 1963 and Pichidangui on 5 January 1980 were fatal and probably caused by the white shark, *Carcharodon carcharias*. The third, a non-fatal attack, was at Totoralillo and probably caused by a white shark or mako shark, *Isurus oxyrinchus*. Shark attack and diver behavior are compared to those in North America. Suggestions concerning diver safety are presented.**

## INTRODUCTION

The white shark, *Carcharodon carcharias,* is responsible for the majority of shark attacks upon humans worldwide in temperate coastal waters (McCosker 1981). Three recent attacks on divers off the Chilean coast which resulted in two fatalities appear to have involved white sharks. The senior author investigated those attacks, visited the sites, and interviewed a victim and eyewitnesses. Thorough medical study, when possible, was made. In California and Oregon, the white shark is implicated in at least 40 attacks on humans and at least five fatalities since 1926 (Miller and Collier 1981; and R. N. Lea unpublished data). The similarities of the attacks on Chilean divers to those on divers in the northeastern Pacific has allowed us to make an analysis and comparison of white shark behavior in widely separated areas.

The Chilean coastline is over 3200 km long, reaching from subtropical waters in the north to subantarctic waters at the tip of the continent (Figure 1). Where accessible from the shore or by small boat, much of the coastline is exploited for its shallow water marine resources. These include the edible sea urchins, the large gastropod called "loco" (*Concholepas concholepas*) which is much like the abalone (*Haliotis* spp.) in terms of its ecology and desirability by humans, and an increasing amount of spearfishing. Since shallow inshore areas of most of the accessible coastline have been heavily collected, diving for these resources is now increasingly necessary. Spearfishing is becoming popular, both recreationally and commercially. At any given time of the day, hundreds of divers are working the Chilean coastline, primarily in the central part of Chile from 29° to 37° S lat. Divers customarily wear full rubber wet suits and many of them dive with the aid of hookah to depths as great as 40 m. Such divers are usually aided by an airline tender and a boatman. Scuba diving was, until recently, relatively unknown in Chile.

We further note that many places are found along the Chilean coast which serve as haulout sites for pinnipeds. Like similar North American locations, these rocky headlands and associated offshore reefs provide habitat for exploitable marine resources. In that white sharks feed, as adults, primarily upon pinnipeds

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and are located in the vicinity of marine mammal populations, it is perhaps surprising that more shark attacks on man have not been reported from this coast. The following case histories are the first, to our knowledge, which have occurred in Chile.

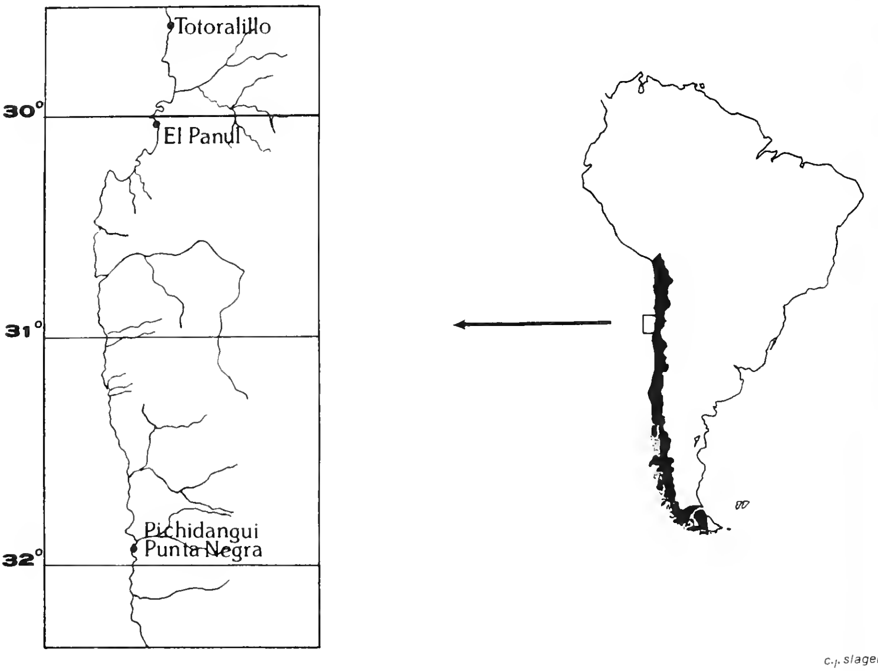


FIGURE 1. Shark attack locations along the Chilean coast.

## ATTACK 1. BAHÍA EL PANUL

El Panul is a small coastal indentation about 12 km south of Coquimbo. The boulder-strewn shoreline has sea lion haulout areas within 800 m of the attack site. The attack occurred on 29 September 1963 at ca. 1100 h on a clear and sunny day. Crisologo Urizar G., a sport diver wearing a .64 cm black nylon-lined wet suit with a yellow weight belt and blue "Cressi Rondine" fins, mask, and snorkel, was spearfishing with a partner over a sand and kelp-covered bottom. At the time of the attack, Urizar was about 50 m offshore in close proximity to a semi-submerged rock formation in the center of the bay. A gentle current, moving in a SE direction, was noticed. The divers had been spearing adult sheephead wrasse, *Semicossyphus maculatus,* for 45 min. and had attached them to a stringer on their weight belts.

Immediately prior to the attack, the diver's partner saw Urizar signal that he was about to dive for a fish on a rock formation. The witness then hyperventilated, began to descend, and noticed a large "gray shark," about 1 m below the

surface and 3 m away from him, with the victim's blue metallic speargun trailing from the shark's mouth by the spearline. He also noticed a white object in or near the mouth which he was unable to identify. The witness recovered one of the victim's floating fins, and then swam to shore. He climbed to a vantage point and observed a 2 m surface patch of bloodstained water next to the rock formation with a flock of gulls at the surface. The shark had returned to the attack site with its dorsal and caudal fins plainly visible; the shark then submerged. Within two hours of the attack, an underwater search was carried out but no remains of the victim were found. The victim's wet suit jacket, severely gashed, washed ashore. A line was set on the morning of 30 September to catch the shark; two large hooks, each baited with 2 kg of horsemeat, were suspended at the attack site to a depth of 2 m. The lines were attached to a 24 m tether strung between two 120 l drums, from which bloody horsemeat was dripping. The line was anchored at each end by a 50 kg concrete block. The following morning the line had been torn away and the drums were found heavily battered. The shark was not sighted again.

From discussions with the witness and an examination of the wet suit remains, it appears that the shark was at least 4 m long. The size and the attack behavior would suggest that it was either a white shark or a tiger shark, *Galeocerdo cuvier.* The water temperature at the site was not measured, but is usually 12°–14°C at that time. The temperature is appropriate for *Carcharodon* and is very similar to that of California waters north of Pt. Conception. The presence of pinnipeds in the immediate vicinity also increases the likelihood that the locality would be inhabited by *Carcharodon.*

## ATTACK 2. PUNTA NEGRA

José Larenas Miranda was fatally attacked on 5 January 1980 at Punta Negra, 7 km S of Pichidangui. This attack was recorded in a Valparaiso newspaper account (García and Inzunza 1980) and by Balbontín and Reyes (1981); we herein analyze and supplement their data. Miranda was hookah diving for locos along a steep rocky shoreline. The sea was calm, the day windless and overcast, water temperature was approximately 16°C, and the water visibility was about 8 m. The victim was diving from a 7 m wood boat and was wearing a complete black neoprene wet suit with black fins and mask. He carried a collecting bag in his left hand and a pry bar in his right. At 1100 h he had completed a 35 min dive during which he had speared fish and collected locos. He moved to a second site which was within 150 m of a sea lion haulout. During several days preceding the attack other divers had seen parts of sea lion bodies on the bottom near the attack site; the cause of their death (possibly human induced) was not obvious.

At the attack site, the boat was 20 m from shore, over 1 m of water. The diver entered the water, swam 5 m from the boat and descended obliquely. After about one minute, the diver's forward progress stopped and the bubbles stopped rising. Pressure began to build in the accumulator tank and then a mass of bloody bubbles ascended. Immediately thereafter, the head and anterior trunk region of an immense shark broke the surface about 3 m from the boat. From the shark's jaws were visible the victim's decapitated upper torso and the left arm and shoulder (Figure 2). The shark then dislodged the remains, which was hanging from its mouth by the shards of the wet suit, and briefly submerged in a circling

pattern. The shark soon reappeared with its head above water and its mouth open. Nearby boats rapidly came to the site as the shark continued to circle the body and occasionally mouth it. Motormen of the approaching boats tried to drive off the shark by revving their motors. This partially succeeded and the men in the victim's boat were able to recover the body, now exsanguinated. As they were doing this, the shark attempted to snatch away the body, passing close by and biting its right arm. The shark moved off about 15 m from the boat and then proceeded to attack the boat at high velocity with its head out of the water and its mouth open. The boatman managed to turn the boat obliquely to avoid the collision and the impact was taken on the left stern, lifting the boat from the water and turning it 90°. The boatman started the motor in an attempt to escape but the shark then violently bumped the prow with side thrusts of its head. The shark's snout was even with the prow of the boat and its tail was seen to extend about 1 m beyond the stern. It was seen to be as broad as the boat's beam (1.4 m). The boatman guided the boat to shoal water and the shark followed and became grounded. The crew escaped before the shark freed itself. The shark was briefly sighted the next day after which it was not seen again. The shark was described by witnesses to be brown-gray dorsally and white ventrally. The dorsal fin was broadly triangular and the tail lobes appeared subequal. It was estimated to be more than 7 m long. On the basis of the attack behavior and the nature of the wounds, it is most likely a *Carcharadon.*

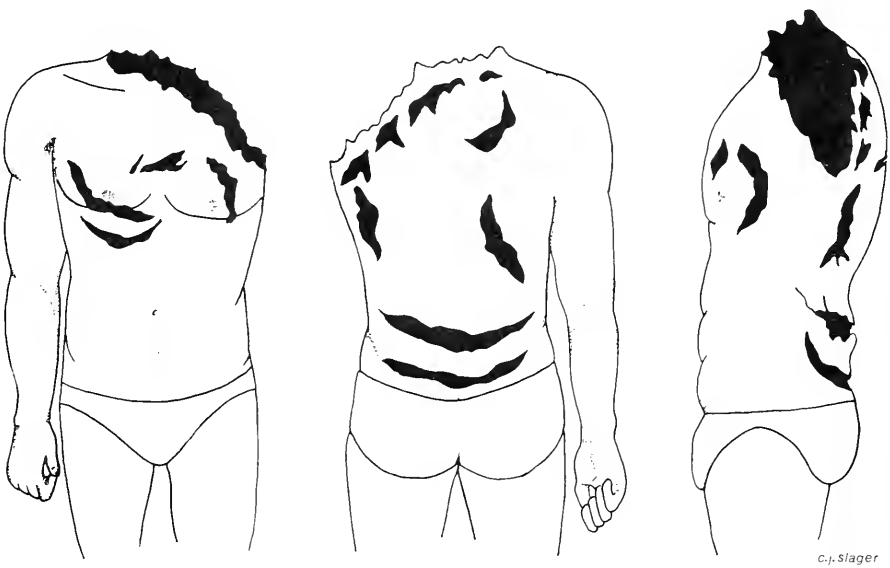


FIGURE 2. Illustration of cadaver of José Larenas Miranda, attacked at Punta Negra.

Observations by witnesses and the character of the wounds sustained suggest that the victim saw the shark coming and tried to fend it off with his left arm. Secondary wounds inflicted on the cadaver as it floated belly down show that the shark continued to attack the wounded and bleeding upper torso. The

displacement of the dorsal and ventral wounds on the body indicate that the weight belt may have interfered with the shark's lower jaw. Thoracic wounds were probably produced by lateral teeth.

Autopsy at the Los Vilos Hospital on 9 January showed decapitation at the 7th cervical vertebra, including amputation of the shoulder and left arm. The clavicle was lost, as was part of the scapula and a mass of corresponding dorsal musculature. The wounds were surrounded by jaggedly cut skin. The midsection was wounded due to secondary bites by the shark, producing both dorsal and ventral lacerations, vertebral and rib fracture, lung penetration, and penetration of the abdominal cavity. The right arm showed a 6 cm laceration inside the elbow. No shark tooth fragments were found.

## ATTACK 3. BAHÍA TOTORALILLO

Carlos Vergara M. was attacked at Bahía Totoralillo, ca. 80 km N of Coquimbo, on 4 March 1981. He was diving ca. 700 m from a sea lion haulout area, along a rocky shoreline which gently sloped to depth. Sea surface was calm, surface temperature was 16°–18° C, and the turbid water had 2–3 m visibility. He and two other sport divers wore full black neoprene wet suits, black fins and masks, lead weight belts, and carried arbalette spearguns. They had been spearing fishes in depths of 3–5 m for ca. 45 minutes prior to the attack at about 1030 h. None carried speared fishes. About three hours earlier, fishermen in a small boat had been dynamiting schools of mackerel near the site. Sea lions had been seen in the area scavenging discarded fishes. The men had entered the bay at its southern point and had advanced in a line parallel to the coast, separated from one another by a distance of about 10–15 m. The victim was trailing and located a flounder which he pursued with difficulty due to turbidity. He reached a point about 50 m offshore at about 5 m depth, and dived vertically about 1.5 m to view the bottom. As he did so, he was seized firmly by the right foot and dragged toward the bottom. Looking down, he saw the head of a shark which he estimated to be 30–40 cm in breadth. The shark was roughly estimated to be 2 m long and dark in color. He was able to see, but not in detail, the eye of the shark and its dorsal fin, which he described as being broadly triangular. Unable to free his foot, he violently stamped on the shark's head with the heel of his left foot, at which the shark freed him, turned and swam away. The victim swam rapidly to shore, where his friends helped him from the water. The boot of his wet suit had been slashed, and he had suffered two deep lacerations of 6 and 8 cm length which bled profusely (Figure 3). There was an extensive zone of erosion and contusion around the wounds. First aid was administered at the site and he was taken to the hospital for suturing. The shark was not seen again. No teeth fragments were found in the victim.

The identity of the attacking shark is not clear. The behavior would suggest that it was a young white shark, however the puncture wounds (rather than deep lacerations) might indicate a more pointed dentition, such as that of a mako, *Isurus oxyrinchus*. Randall and Levy's (1976) description of a mako attack in the Red Sea suggests a similar attack scenario. The dynamiting of fish was probably attractive to the shark, as well as to the sea lions, which would be a further attractant to a lamnid shark. White sharks about 2 m usually feed on fishes. They do not attack pinnipeds until they are about 3 m in length. The teeth of 2–3 m

*Carcharodon* are considerably more pointed than those of an adult (Tricas and McCosker 1984), and would tend to leave puncture wounds as well as a slash mark. This fact, as well as the proximity of the shark to shallow water (unlikely for a mako), would favor the identity of the attacker as a white shark rather than a mako, which prefers warmer offshore waters.

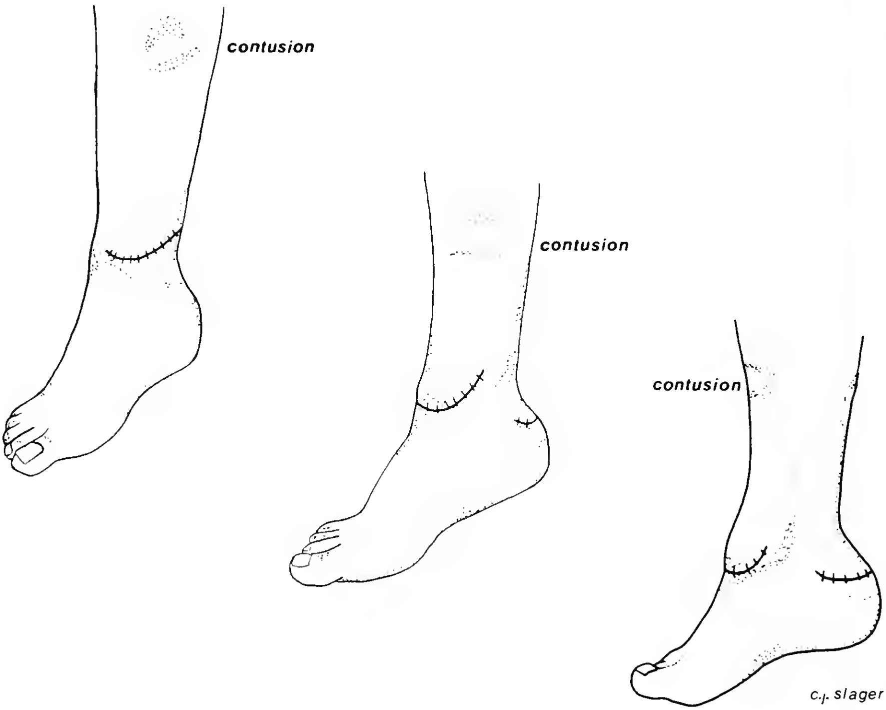


FIGURE 3. Diagram showing various aspects of right foot of Carlos Vergara M., attacked at Bahiá Totoralillo.

## COMPARISON TO ATTACKS IN CALIFORNIA

The attack scenarios described above are similar to those off southern Australia (Coppelson 1963) and off California and Oregon (Miller and Collier 1981). Noteworthy similarities include: offshore attacks beyond algal beds (although in shallow water); the wearing of black neoprene wet suits by divers; and surface diving after hyperventilation and diving in the immediate vicinity of pinniped rookeries. These conditions suggest that, as happens elsewhere in temperate waters, white sharks mistake the appearance and behavior of divers for pinnipeds, their normal prey.

It is significant that two of the three Chilean divers died as a result of the attacks, whereas only five of ca. 40 attack victims have died in California and Oregon. It is also significant that deaths in North America resulted from massive blood loss, rather than significant consumption by the sharks. We account this

to a difference in human rather than shark behavior. In North America, it is customary for divers and swimmers to enter the water in pairs or groups, such that once attacked, a victim is nearly immediately taken from the water. It is typical of white sharks to attack with one massive bite, then wait for five to ten minutes until its victim (either human or pinniped) has bled to death before attempting to consume it, thereby avoiding injury from a wounded but struggling prey. This supposed "bite and spit" paradox was previously interpreted to be related to a distasteful quality of neoprene and/or human flesh, but is now best explained in the above manner (see Tricas and McCosker 1984, and McCosker MS).

In that scuba diving is relatively new in Chilean waters we feel it imperative that divers should be cognizant of the risk of shark attack. As intertidal and shallow water resources become depleted by human behavior, it is likely that more attacks will occur in Chilean waters upon divers. We therefore advise that divers should enter the water in pairs or in groups, particularly in the vicinity of pinniped rookeries, where a chance encounter with a white shark is most likely.

## ACKNOWLEDGMENTS

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# NOTES

## ECOLOGICAL STATUS OF STRIPED BASS, *MORONE SAXATILIS*, IN UPPER NEWPORT BAY, CALIFORNIA

### INTRODUCTION

Each April from 1974 through 1977, the California Department of Fish and Game stocked 10,000–14,000 juvenile striped bass (100–150 mm SL) into the upper Newport Bay estuary in southern California.

In 1978 and early 1979, we (Horn and Allen 1981) completed a comprehensive, multiple-gear survey of the fish populations of upper Newport Bay. This study offered the first opportunity to assess the status of the introduced striped bass in the upper bay environment. The specific objectives of the present paper are, therefore, to provide information on the (i) seasonal abundance and distribution, (ii) size and age composition, (iii) food habits, and (iv) ectoparasite load of the striped bass population.

### MATERIALS AND METHODS

Striped bass were collected by otter trawl and gill net during the bimonthly study (Horn and Allen 1981) carried out from January 1978 through January 1979 at four stations in upper Newport Bay (Lat 33° 37′N, Long 117° 54′W). Standard lengths (mm SL) and weights (g) of fish were recorded in the field. Specimens were fixed in 10% buffered formalin after their guts had been injected with formalin via the anus. We recorded the age of each of 25 specimens of striped bass by counting the annuli on scales taken from midbody just above the lateral line. Stomach contents of each of 26 specimens encompassing the size range of all fish caught were removed, enumerated, identified to the lowest possible taxonomic level and dried to a constant weight in a 60° C oven. Further details of the field and laboratory procedures are described in Horn and Allen (1981).

### RESULTS

We caught 36 striped bass during the study. Fifteen of these, from 201 to 265 mm SL, were collected in otter trawls while 21, mostly larger individuals (240–460 mm SL), were captured by gill net. The smallest fish (201 mm SL) weighed 150 g while the largest fish (460 mm SL) weighed 1814 g. Of the fish in which sex was determined, 11 were males and eight were females. Fish ranged in age from two to four years with the majority two years old (Table 1). Most (86%) of the specimens were collected during the first three sampling periods (January, March and May, 1978). The fish may spend the rest of the year in the lower bay and/or adjacent coastal waters, or may be subject to high mortality.

**TABLE 1. Length And Age Relationships For Striped Bass Collected In Upper Newport Bay In 1978–1979.**

| *Length interval (mm SL)* | *Total No. of fish* | *No. fish in each age class* II | III | IV |
|---|---|---|---|---|
| 201–272 | 19 | 19 | – | – |
| 275–356 | 4 | – | 4 | – |
| 345–460 | 2 | – | – | 2 |

The relationship of length and weight was described by the equation $\log_{10}$ weight $= 2.8463 \log_{10}$ length $- 4.3957$.

Stomach contents of the striped bass consisted primarily of fishes, decapod crustaceans, and polychaetes. Fishes were the most frequently occurring items (65% of stomachs). Gobiids comprised the largest proportion (38%) of total dietary items, whereas the topsmelt, *Atherinops affinis*, was the principal component (68%) in terms of total dry weight. The decapods in the stomachs included yellow shore crab, *Hemigrapsus oregonensis*; snapping shrimp, *Alpheus californiensis*, and bay ghost shrimp, *Callianassa californiensis.*

One or more of the fins of approximately 75% of the striped bass was either infested with the cymothoid isopod, *Nerocila californiensis,* or had scars of infestation assumed to be from this ectoparasite. All fins except the dorsal fin were infested.

## DISCUSSION

The principal findings of this study are that (i) some striped bass are surviving and functioning in their expected ecological role several years after being stocked in upper Newport Bay, but (ii) appear to be in relatively poor condition possibly because the upper bay is a suboptimal habitat. The following discussion provides the basis for these conclusions.

In their ecological classification of the upper Newport Bay fish community, Horn and Allen (1981) described striped bass as a member of a periodic, channel-inhabiting species group that during the winter also included striped mullet, *Mugil cephalus,* and deepbody anchovy, *Anchoa compressa.* Striped bass joins California halibut, *Paralichthys californicus;* spotted sand bass, *Paralabrax maculatofasciatus;* and yellowfin croaker, *Umbrina roncador,* as the principal top carnivores in upper Newport Bay (Allen 1980).

Age-size and length-weight relationships of striped bass in upper Newport Bay were generally similar to those determined in other studies in California (Scofield 1931, Robinson 1960). The slope of our length-weight equation is about 5% lower than that ($\log_{10}$ weight $= 3.0038 \log_{10}$ length $- 2.1393$) derived by Robinson (1960) for striped bass from the San Francisco Bay area and lower Sacramento-San Joaquin Delta. The age classes we identified appear to correspond to fish planted in the upper bay in the four years prior to our study. That is, our age group II fish probably represented the 1976 and/or 1977 introductions, age class III the 1975 and/or 1976 introductions, and age class IV the 1974 and/or 1975 introductions.

Our study suggests that the striped bass in upper Newport Bay constitute a nonbreeding population. We base this conclusion on the lack of mature or maturing gonads in individuals old enough to be in breeding condition (2–3 yrs

for males, 4–5 yrs for females—see Setzler *et al.* 1980) and the absence of both eggs and larvae of striped bass in the ichthyoplankton samples taken during the 1978–79 study. Furthermore, striped bass are probably unable to spawn in the upper bay because of the lack of suitable spawning conditions. Spawning generally occurs in fresh or nearly fresh waters in the late spring and summer (March–July, peak in May and June) as temperatures reach 15–20° C (Westin and Rogers 1978; Setzler *et al.* 1980). Although upper bay temperatures are appropriate for spawning during these months, the small volume of fresh water entering the upper bay during this period of the year may be inadequate to stimulate or sustain reproductive activity.

The high infestation frequency of ectoparasites may have a detrimental effect on the striped bass population. Several of the largest fish we caught had lost virtually all of their fins to the isopod parasites. Such severe fin damage must reduce swimming and presumably feeding capabilities. Setzler *et al.* (1980) in their summary of striped bass parasites listed two isopods (in genera other than *Nerocila*) known to occur on the fish, but reported a much lower infestation frequency (< 1 to 4%) than we found for *N. californiensis* on the upper bay striped bass population. The heavy ectoparasite load of striped bass in the upper bay may be consistent with a pattern we have generally observed, namely that bay-estuarine fish populations have a higher frequency of ectoparasite infestations than conspecifics in open coastal waters.

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# FOOD HABITS OF BLACK-TAILED DEER, *ODOCOILEUS HEMIONUS COLUMBIANUS*, IN TRINITY COUNTY, CALIFORNIA

Rumen contents from 40 black-tailed deer in Trinity County, California, were analyzed to determine their food habits. Between 16 December 1979 and 5 February 1980, we shot 10 deer from the Weaverville herd and 9 from the Hayfork herd. Between 21 March and 22 April 1980, 11 Weaverville and 10 Hayfork deer were collected. Herd boundaries, habitat descriptions, methods of collection and analysis, and information on the physical condition of individual deer are presented by Kie, Burton, and Menke (1984).

During early winter, Weaverville deer diets, by volume, consisted of browse (91%), forbs (3%), and grasses and grasslike plants (6%) (Table 1).Ceanothus species made up 71% of the diet, with wedgeleaf ceanothus accounting for 39%. Hayfork deer ate less browse (63%), and more forbs (11%) and grasses (26%) early in winter than did Weaverville deer (Table 1). White fir (10%) and Douglas-fir (13%) contributed substantially to Hayfork deer diets in early winter, but less to diets of Weaverville deer. Hayfork deer also ate more grasses in early winter. However, availability of different forage classes to each herd was not measured.

**TABLE 1. Percent by Volume of Forage Species in Rumens of Deer from the Weaverville and Hayfork Herds Collected During Early Winter (16 December 1979 to 5 February 1980) and Late Winter-spring (21 March to 22 April 1980) in Trinity County, California. Number of Deer Collected in Parentheses, Tr = Trace Amounts.**

| *Forage species* | *Weaverville* early (10) | *Weaverville* late (11) | *Hayfork* early (9) | *Hayfork* late (10) |
|---|---|---|---|---|
| | | *Percent* | | |
| Browse | | | | |
| White fir (*Abies concolor*) | 4 | – | 10 | – |
| Chamise (*Adenostoma fasciculatum*) | 2 | 3 | 7 | 2 |
| Greenleaf manzanita (*Arctostaphylos patula*) | 5 | 16 | 3 | 3 |
| Whiteleaf manzanita (*A. viscida*) | Tr | 6 | 2 | Tr |
| Ceanothus (*Ceanothus* spp.) | 9 | – | – | – |
| Wedgeleaf ceanothus (*C. cuneatus*) | 39 | 1 | 10 | 13 |
| Lemon ceanothus (*C. lemonii*) | 22 | 5 | 3 | 5 |
| Deerbrush (*C. integerrimus*) | 1 | – | – | – |
| Mountain whitethorn (*C. cordulatus*) | – | – | 5 | 6 |
| Squaw carpet (*C. prostratus*) | – | – | 1 | – |
| Mountain mahogany (*Cercocarpus betuloides*) | Tr | 6 | Tr | 6 |
| Yerba santa (*Eriodictyon californicum*) | 3 | – | 1 | – |
| Silk-tassel (*Garrya fremontii*) | – | Tr | – | – |
| Toyon (*Heteromeles arbutifolia*) | Tr | – | – | – |
| Incense-cedar (*Libocedrus decurrens*) | 2 | – | 5 | 1 |
| Honeysuckle (*Lonicera* spp.) | – | 2 | – | – |
| Pine (*Pinus* spp.) | Tr | – | – | – |
| Stonefruits (*Prunus* spp.) | – | – | – | Tr |
| Douglas-fir (*Pseudotsuga menziesii*) | Tr | 7 | 13 | 14 |
| Interior liveoak (*Quercus wislizenii*) | – | 1 | 1 | – |
| Hollyleaf redberry (*Rhamnus crocea*) | Tr | – | – | – |
| Sierra gooseberry (*Ribes roezlii*) | – | 2 | – | Tr |
| Snowberry (*Symphoricarpos mollis*) | – | 5 | – | 4 |
| Other | 4 | 1 | 2 | Tr |
| Subtotal | 91 | 55 | 63 | 55 |

**TABLE 1. Continued**

| | | | | |
|---|---|---|---|---|
| Forbs, fungi, lichen | | | | |
| Mountain dandelion (*Agoseris* spp.) | – | – | – | Tr |
| Sunflower family (*Compositae*) | – | 2 | – | Tr |
| Filaree (*Erodium* spp.) | – | Tr | – | 2 |
| Redstem filaree (*E. cicutarium*) | – | – | 2 | – |
| Bedstraw (*Galium* spp.) | – | – | – | Tr |
| Geranium (*Geranium* spp.) | – | Tr | – | Tr |
| Waterleaf (*Hydrophyllum* spp.) | – | – | – | Tr |
| Mint family (Labiatae) | – | Tr | – | – |
| Pea (*Lathyrus* spp.) | – | 1 | – | Tr |
| Peppergrass (*Lepidium nitidum*) | – | Tr | – | – |
| Lotus (*Lotus* spp.) | – | 1 | 1 | Tr |
| Lupine (*Lupinus* spp.) | – | Tr | – | Tr |
| Miner's lettuce (*Montia perfoliata*) | – | – | 1 | 3 |
| Popcorn flower (*Plagiobothrys* spp.) | – | Tr | 1 | – |
| Crowfoot family (*Ranunculaceae*) | – | – | – | Tr |
| Madder family (Rubiaceae) | – | Tr | – | Tr |
| Thimbleberry (*Rubus parviflorus*) | – | 3 | – | – |
| Clover (*Trifolium* spp.) | – | – | Tr | Tr |
| Vetch (*Vicia* spp.) | – | – | – | Tr |
| Other forbs | – | Tr | – | – |
| Fungi (Basidiomycetes) | 2 | Tr | 2 | – |
| Crustose lichen (Lecideaceae) | – | Tr | 1 | 1 |
| Foliose lichen (Parmeliaceae) | Tr | Tr | 1 | Tr |
| Fruticose lichen (Usneaceae) | 1 | 2 | 2 | Tr |
| Mistletoe (*Phoradendron flavescens*) | – | – | Tr | – |
| Subtotal | 3 | 9 | 11 | 6 |
| Grasses, grasslike | | | | |
| Grasses (Gramineae) | 6 | 36 | 26 | 39 |
| Rushes (Juncaceae) | – | Tr | – | – |
| Subtotal | 6 | 36 | 26 | 39 |
| Total | 100 | 100 | 100 | 100 |

During late winter-early spring, consumption of different forage classes by Weaverville and Hayfork deer was nearly identical. Weaverville deer consumed 55% browse, 9% forbs, and 36% grasses; and Hayfork deer, 55% browse, 6% forbs, and 39% grasses (Table 1). However, species of browse and forbs eaten by each herd differed. Furthermore, differences in grass species eaten may have also occurred, although individual species were not identified.

Consumption of all ceanothus species by Weaverville deer dropped from 71% to 6% between collection periods; consumption of wedgeleaf ceanothus dropped from 39% to 1%. The percentage of wedgeleaf ceanothus in Hayfork deer diets remained nearly constant at 10–13%. These results may be explained in several ways: in early winter, Weaverville deer heavily used ceanothus growth from the previous growing season; or Hayfork deer had greater access to forbs and grasses than did Weaverville deer. Hayfork deer ate mountain whitethorn during both collection periods; Weaverville deer did not appear to eat it at all. Consumption of the deciduous deerbrush was low during both collection periods, even though it grew where many of the deer were collected and new leaves were present by late winter-early spring.

In most cases, food items were related to habitat types from which the deer were collected. Consumption of chamise was relatively low by all deer, and was related to local availability. Three Weaverville deer that had eaten chamise

(17% of their individual diets) were all collected where chamise was abundant. All four of the Hayfork deer that had eaten chamise (22% of their diets) were also collected where it was abundant. Higher proportions of white fir, Douglas-fir, mountain whitethorn, and incense-cedar in the diets of Hayfork deer than in those of Weaverville deer reflected the availability of those forage species at the higher elevation, mixed-conifer sites where many of the Hayfork deer were collected. We suggest that deer selected some habitats with desirable forage (third order selection) and then chose forage species within those habitats (fourth order selection) (Johnson 1980).

We believe that the relatively poor physical condition in Weaverville deer reported by Kie, Burton, and Menke (1984) was correlated with diet. Consumption of large amounts of wedgeleaf ceanothus and small amounts of grasses by Weaverville deer in early winter suggests that they should have been in better condition than Hayfork deer. Most ceanothus species are taken readily by deer in California (Dixon 1934, Leach and Hiehle 1958). Mature grasses, low in digestible nutrients, are not readily used by deer (Nagy, Hakonson, and Knox 1969). However, the concept that deer are browsers rather than grazers by choice has been questioned (Wilson 1969, Gill 1976), and Evans (1976) has suggested that high consumption of wedgeleaf ceanothus by deer may be related to lack of more palatable forages. Furthermore, the volume of vigorously growing, green grasses in the diets of black-tailed deer in the spring has been estimated to be as as high as 55% in Tehama County (Leach and Hiehle 1958:171) and 90% in Mendocino County, California (Longhurst *et al.* 1979:221).

It appeared that Weaverville deer collected on winter ranges were in poorer condition than Hayfork deer (Kie, Burton, and Menke 1984). We found that over one-third of the early winter diet of Hayfork deer consisted of grasses and forbs. Therefore, we suggest that in addition to prescribed burning (Kie and Menke 1980), seeding of grass-forb mixtures to provide abundant herbaceous forage in early winter should be investigated.

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## ADDITIONAL NOTES ON THE REPEAT SPAWNING BY PACIFIC LAMPREY

Prior to Michael's (1980) report of repeat spawning for Pacific lamprey, *Lampetra tridentatus,* it was assumed adults died after spawning (Wydoski and Whitney 1979). The report of repeat spawning drew several responses and comments. This paper will attempt to answer questions raised in the letters, and further examine the data from Snow and Salmon creeks.

The Washington Department of Game operated permanent fish traps near the mouths of the Snow and Salmon creeks December 1977–June 1981. The streams are located on the northeastern corner of the Olympic Peninsula and drain into the Strait of Juan de Fuca. The traps operated year-round and trapped upstream and downstream migrants. Lampreys captured in the traps were measured to the nearest millimetre total length (TL). During September to mid-February the traps were selective and did not capture all lampreys migrating past them. This allowed an unknown number of lampreys to pass upstream undetected. When the smolt trapping screens were installed in mid-February, the traps captured all lampreys longer than about 200 mm TL.

Upstream migrating adult lampreys were captured from September through May. Most were trapped during periods of high streamflow. Downstream migrating lampreys were trapped in the spring, mostly during May.

Both upstream and downstream migrant adult anadromous Pacific lampreys were observed in Snow and Salmon creeks (Figure 1). Upstream migrants were generally longer than 440 mm TL, while downstream migrants were generally less than 430 mm TL. The absence of fish less than 420 mm TL captured as upstream migrants was due to the smaller fish passing through the traps undetected. Fish as large as 600 mm TL had been observed to squeeze through the trap pickets. The absence of downstream migrants greater than 440 mm TL is probably due to post-spawning mortality, as the smolt trapping screens in operation at the time would stop all downstream migrating adults. Some of the adult downstream migrants ("kelts") had eggs which were easily extruded, suggesting the fish

were mature and capable of spawning. Operational considerations precluded trapping all upstream migrants at Snow and Salmon creeks, so it is not possible to determine the magnitude of the run or the relative abundance of the two groups.

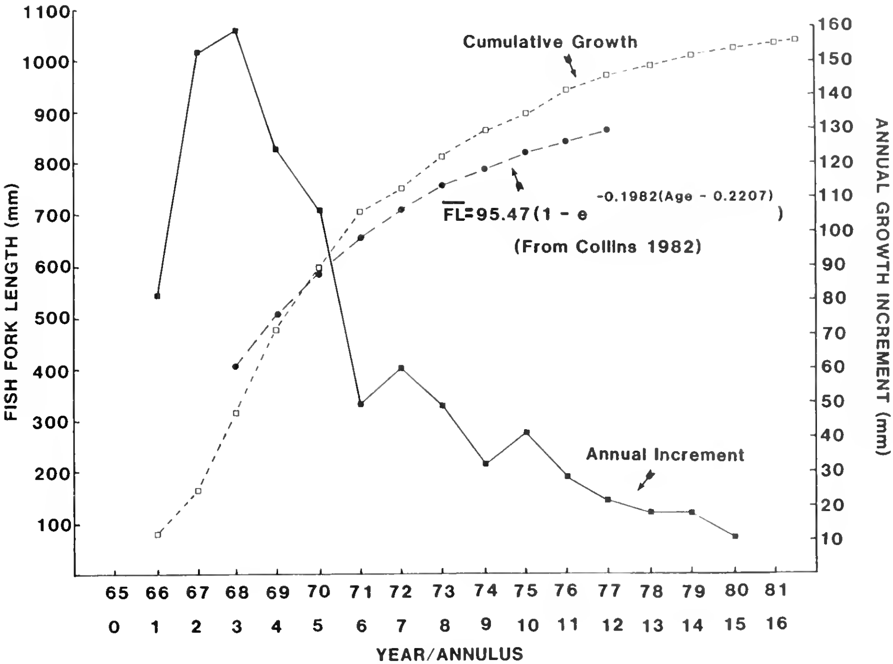


FIGURE 1. Length frequency distribution for adult lampreys captured in traps on Snow and Salmon Creeks.

Downstream migration of adult lampreys has also been documented by Washington Department of Game personnel operating downstream migrant traps on the Kalama River system in southwest Washington. In 1979, Chilcote, Leider, and Crawford (1980) estimated over 7,000 adult lampreys moved downstream. The 1981 estimate for Kalama River was greater than 13,000 (S. Leider, Wash. Dept. of Game biologist, pers. commun.). Leider indicated that most of these fish were in good condition when captured in the Kalama River. Washington Department of Fisheries biologist D. Seiler (pers. commun.) has also trapped downstream migrating "adult" Pacific lampreys in some Puget Sound streams. The general appearnace and size of fish were similar to that observed in Snow and Salmon creeks.

Several questions have been put forth by other individuals concerning the report of repeat spawning by Pacific lamprey.

John Heinrich (U.S. Dept. of Interior biologist, Marquette, Michigan) suggested that the marks observed on the returning adults were natural. In his experience with sea lamprey, *Pteromyzon marinus,* fin marks occurred naturally. It is possible that the initiation of a marking program resulted in closer examination

of the lampreys. Still, the marks were only noted after marking was initiated and not seen after marking ceased.

Dr. R. J. Beamish (Director, Resource Services Branch of the Pacific Biological Station, Nanaimo, Canada) suggested that the smaller lampreys, the "kelts", were fish that would remain in freshwater for 12 months prior to spawning, as had been observed in Babine Lake. However, extensive electrofishing surveys in the Snow and Salmon creeks failed to find lampreys, other than ammocoetes, during the summer months. The marked fish also showed substantial growth between captures. It is unlikely that the small creeks could provide sufficient food for adults to grow as much as was observed. Minimum growth observed at Salmon Creek (largest marked "kelt" to smallest ingeminator) was 19 mm and maximum (smallest "kelt" to largest ingeminator) was 284 mm.

The other comments simply stated that based on the writers' experience, it was not possible for lampreys to spawn more than once. The observations at Snow and Salmon creeks indicate that Pacific lampreys can survive two returns to saltwater; the first follows smolting and the second appears to follow spawning. The adult fish captured on downstream migrations had all the external appearances of spawning conditions: abrasions, pale body color, easily extrudable eggs, etc. Marks were applied to some of these fish, and during the following spawning season some marked upstream migrants were captured. These fish were substantially larger than when marked, indicating they found a good food source.

A number of respondents mentioned that their studies of lamprey (mainly the sea lamprey) physiology proved that they all died after spawning. Similar remarks have been and are still being made for Pacific salmon, *Oncorhyncus* spp., even though there have been reports since the 1950's (Robertson 1957) that some chinook, *O. Tshawytscha,* and perhaps kokanee, *O. nerka,* survived successful spawning and became sexually mature the following year. The observations on chinook were from hatchery-reared fish; the kokanee were wild.

Circumstantial evidence suggests that the Pacific lamprey can spawn more than once, since marked fish which appeared to be mature were captured on succeeding spawning runs and showed substantial growth between captures. The presence of downstream migrations of healthy adult Pacific lampreys in several streams in Washington suggests that the observations from Snow and Salmon creeks are not isolated. Further study is necessary to determine the life history and taxonomic status of Washington's Pacific lampreys. It is possible that a taxonomic investigation similar to Beamish's (1982) work in British Columbia will prove illuminating.

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# A NORTHERN FUR SEAL, *CALLORHINUS URSINUS,* FOUND IN THE SACRAMENTO-SAN JOAQUIN DELTA.

Pinniped sightings in rivers and estuaries of the west coast of North America are on the increase. Harbor seals, *Phoca vitulina,* California sea lions, *Zalophus californianus,* and Steller sea lions, *Eumetopias jubata,* have been reported (Paulbitski 1974; Sitts, Hayes, and Knight 1978). However, there are no recorded sightings of northern fur seals, *Callorhinus ursinus,* in inland waters of the west coast.

On 6 December 1981 the California Marine Mammal Center (CMMC) received a rescue call from the Port of Stockton, San Joaquin County, California. Mr. Bob Gaides had been salmon fishing with his family, an estimated 144 km upstream from the Pacific Ocean on the Sacramento River in the canal across from the Port of Stockton turning basin. They saw an animal they throught to be a beaver swimming around the boat, but as it came closer, they realized it was a small seal. They picked the animal up in their fishing net and called CMMC.

On admission to CMMC the animal was identified as a 9Kg, 0.6m long, six month old, female northern fur seal. The northern fur seal is normally totally pelagic during the winter months off the coast of California unless injured or diseased (Daugherty 1979). The animal had pink mucous membranes, complete dentition, and was alert; medically it had a soft cough and was constipated.

Fecal samples were obtained for dietary analysis and parasitic examination. No conclusions on the animal's feeding patterns could be determined and parasitic examination was negative.

Following two and one-half months of rehabilitation involving laboratory tests, radiography, respiratory therapy, antibiotics, and a weight gain of 2.25Kg, the animal was released at Southeast Farallon Island, 43 km west of San Francisco on 27 February 1982.

On 8 March 1982, the animal was again picked up, this time in Berkeley, California, having been hit by a car.

Why then did this animal, a species which has the most pelagic distribution of all north Pacific pinnipeds, on two occasions swim inland? This individual's birth, migration, and feeding habit histories are unknown. Human-animal interaction at an early age might be suspected, since the animal was noted as being "friendly" when initially netted by Mr. Gaides in the Sacramento River. At CMMC the animal was aggressive and at no time exhibited disorientation.

It has been suggested that pinnipeds swim upstream and inland in search of food or territory (Sitts, Hayes, and Knight 1978); in this individual's case, the problem may have been medical impairment. The animal has been placed in a display facility.

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# EXTREME MERCURY CONCENTRATIONS OF A STRIPED BASS, *MORONE SAXATILIS*, WITH A KNOWN RESIDENCE TIME IN LAHONTAN RESERVOIR, NEVADA

In September 1981, a male striped bass, *Morone saxatilis*, introduced into Lahontan Reservoir, Nevada in 1965 was found freshly dead, apparently from natural causes. It weighed 15.2 kg and was 104 cm fork length. This bass is unusual for two reasons: it's known residence time and it's tissues contained extremely high concentrations of mercury. Since the species is a voracious piscivore at the highest trophic level and the fish was in the reservoir for 16 years, the bioaccumulation of mercury in this fish probably represents maximum values.

This bass is known to have been stocked in 1965 because about 4,000 striped bass were seined from the Sacramento-San Joaquin Delta, California, and stocked into Lahontan Reservoir, during that year. There is no evidence of subsequent reproduction, stocking was discontinued (Nevada Department of Wildlife, unpublished data), and scale analysis by the California Department of Fish and Game's Bay-Delta project indicated it was 16 years old. Because of the small population size, striped bass are not generally caught by anglers in Lahontan Reservoir.

Lahontan Reservoir, 72 km southeast of Reno, was created in 1915 when the Carson River was impounded for the Newlands Irrigation Project. The reservoir has a surface area of 4,410 ha. It receives the entire flow of the lower Carson River and about 27.5% of the total flow of the Truckee River. In addition to storage of irrigation water, the reservoir is one of the most heavily used recreation areas in northern Nevada.

Richins and Risser (1975) previously documented that fish in the Carson River system, including Lahontan Reservoir, contained levels of mercury in muscle tissue which exceeded concentrations considered safe by the U.S. Food and Drug Administration (FDA). Mercury was introduced into the Carson River during the mining of gold and silver which was discovered in 1859 in the Comstock Lode, near Virginia City. During the 30-yr peak of the Comstock (1865–1895) it is estimated that 200,000 flasks of mercury or $6.75 \times 10^6$ kg were lost in the milling process; only 0.5% of the amount was later recovered (Bailey and Phoenix 1944).

The objectives of this note are: (i) to document the concentrations of mercury found in the tissues of this striped bass, and (ii) to compare its growth to growth of striped bass from other areas.

Cold vapor atomic absorption was used to determine mercury concentration in several tissues. Procedures followed Stewart (1977). Approximately 10 g of muscle tissue was taken below the dorsal fin and above the lateral line and macerated in a tissue grinder. Whole liver and heart tissues were prepared similarly. The wet tissue was weighed, lyophilized and reweighed to determine percent moisture. The dried sample was then ground to a powder with a mortar and pestle and weighed in a teflon parr bomb cup with 2.5 ml concentrated $HNO_3$, 1.9 ml of 30% $H_2O_2$ and 25 mg $K_2S_2O_8$. The sample was then digested in a parr bomb for 8 h at 100–110°C.

Recovery of mercury from fish samples spiked prior to digestion averaged 92.1 percent. Results are presented as the concentration of total mercury per wet weight of tissue. Cumulative length and incremental growth at each annulus and corresponding year was estimated by measuring the distance between annuli on a scale of the striped bass and back-calculating the fish length at each annulus by direct proportion.

Total mercury concentration in the striped bass muscle tissue was 9.52 mg/kg; i.e., over nine times the 1 mg/kg tolerance level established by the FDA for edible fish tissue. Likewise the concentrations in heart and liver tissue were excessive, 5.58 and 23.65 mg/kg, respectively.

The concentrations of mercury in the Carson River drainage appear to be extreme in relation to other drainages in the United States. Muscle mercury concentrations ranged from 0.11 to 3.95 mg/kg in 56 fish of 10 species collected from the reservoir in 1981 (Cooper 1983). Elsewhere in the Carson River system, concentrations as high as 11.5 mg/kg (carp, *Cyprinus carpio*) in muscle have been observed (Ekechukwu 1976). Striped bass from the Sacramento-San Joaquin River system, California, have been found with up to 2.0 mg/kg mercury (California Department of Fish and Game, unpublished data). The highest recorded mercury levels that we have been able to find for freshwater fish in the Western Hemisphere were reported for fish taken from the highly contaminated Clay Lake on the Wabigoon-English-Winnipeg river system, Canada (Bishop and Neary 1976). Walleye, *Stizostedion vitreum;* pike, *Esox lucius;* and burbot, *Lota lota,* had muscle concentrations of 24.0, 27.8 and 24.8 mg/kg, respectively. A largemouth bass, *Micropterus salmoides,* from Calero Reservoir, California had 5.1 mg/kg (Calif. Dept. Public Health 1971); and fish from Lake St. Clair and St. Clair River, Michigan had levels ranging from 5.0-6.0 mg/kg (Turney 1971).

The age of 16 years is relatively old, but not uncommon, for striped bass. Collins (1982) reports the oldest individual from 125,000 scale determinations to be 19 years, with a tag return indicating that striped bass can live to at least age 23.

The growth of our bass was slightly greater than the growth which Collins (1982) estimated for males in the Sacramento-San Joaquin Estuary (Figure 1). This result agrees with reports of many landlocked freshwater populations (Wilson and Christenson 1965, Goodson 1966, Allan and Roden 1978) having faster growth than their marine counterparts (Robinson 1960, Talbot 1966). Therefore, it does not appear that the high mercury concentration interfered with the specimen's growth rate.

## ACKNOWLEDGMENTS

Nevada Department of Wildlife provided data from stocking records. T. Morefield, California Department of Fish and Game, Stockton, analyzed a sample scale and measured the annuli. J. Heidker, Desert Research Institute Water Laboratory, conducted the mercury determinations. The study was funded by the Office of Water Research and Technology (Contract 14-34-0001-0271).

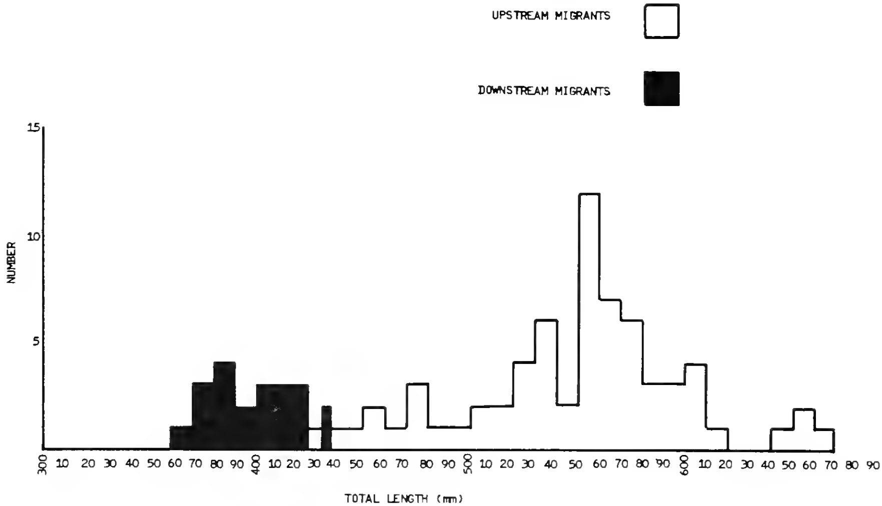


FIGURE 1. Back calculated growth of a male striped bass from Lahontan Reservoir, Nevada (1965–1981) compared to mean growth of male striped bass from the Sacramento-San Joaquin Estuary, California (From Collins 1982).

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